University of Alberta

Market Power, Cost Economies and the Effect of BSE in the North American Beef Cattle Industry

Gabriel John ©

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Abstract

Industry concentration emerging from corporate mergers and acquisitions in the North American beef industry and the incidence of BSE in North America has triggered concerns about market power by the beef packing industry.

Statistically significant oligopoly/oligopsony power and cost diseconomies were found in the North American beef cattle industry. Lack of significant cost economies reduce excess profitability and price mark-ups/mark-downs in this industry. With regional variation, it is evident that regions with large and many plants exert more market power. Despite the fact that we find evidence for market power, the magnitude of its effect is been reduced by market forces of supply and demand, and costs, given the technological base in the industry.

Simulation results show that ranchers' cow calf benefits and fed cattle producer surplus fell in Canada and increased in the U.S. Beef processors' profit fell in Canada, the U.S. and in North American beef packing industry. Consumer surplus was found to have reduced substantially in Canada and the U.S.

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I therefore dedicate this thesis to my late mum, Mrs. Rose Ladi John, may her soul rest in perfect peace; and my dad, Mr. John Malashi for all the financial and moral support they provided me through my entire academic journey. I would like to thank them for being such great role models to me and for encouraging me not to give up even in the midst of storms. I want to also extend this dedication to my siblings Patrick, Martha (post-humous), Michael, Janet, Augustine, Mary and Veronica. I also want to thank the entire Mamman's family for their unconditional love and for being there when I needed them.

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Chapter One: INTRODUCTION

1.1 Background

Substantial changes have occurred in the beef industry over the past two decades including increased consolidation of meat packers and closer coordination along the supply chain. These changes may be attributed to the declining consumption that hit the beef industry during the 1980s and 1990s due possibly to increasing demand for high quality and healthy food products by consumers (Lomeli, 2005), and the BSE crises that continually plagued the industry in the past four years. "The production of differentiated beef products and 'branded beef' is an effort to respond to these consumer demands. However, this has only occurred to a limited extent in the Canadian beef industry, largely due to rigidities in the existing supply chain" (Brocklebank and Hobbs, 2004)

There have been numerous concerns raised across Canada by cattle producers on the exercise of excessive market power by the three federally inspected packers: Cargill, Tyson Foods (Lakeside) and XL Foods, controlling about 80% of the Canadian slaughter capacity (National Farmers Union, 2005).

While the literature displays exhaustive studies of market power in the American beef industry, there are only a few studies addressing market power and the oligopolistic/oligopsonistic concentration of the beef industry in Canada. These studies include Beck and Mozejko (1992), Liu (1991), Cranfield (1995), Cranfield and Goddard (1999), Druhan (1992), Quagrainie (2003); Zhou (1991) and Unterschultz et al, (1997). The victory of cattle producers and ranchers over Tyson Fresh Meats Inc. (formerly IBP), the U.S. largest beef packer in 2004, for manipulating cattle prices by using illegal cattle contracts and exercising excessive market power illustrates some of the effects of oligopolistic/oligopsonistic consolidation in the beef packing industry in the U.S (Corporate Research E-Letter , 2004). However, some studies have recently ascribed 'abnormal' profits of beef packers to economies of scale and scope, which result from cost efficiency and not absolute market power (Morrison 1999; Morrison 2000; Morrison 2001a; Morrison 2001b; Morrison 2003).

1.2 Beef Industry and the Canadian Economy

The Canadian beef cattle industry has, and is still, a large contributor to the Canadian national and provincial economies. It has remained the largest single source of farm cash receipts despite the BSE crises emergent in 2003 ($7.6 billion in 2002, $5.2 billion in 2003, $5.1 billion in 2004 and $5.7 billion in 2005) (Statistics Canada). Beef production added about $20 billion to the Canadian economy in 2004 via its economic contribution in the processing, retail, food service and transportation sectors. This value is down from about $30 billion in 2002 and $21 billion in 2003 (Beef Information Centre, 2005).

In terms of exports, about 60% of the Canadian cattle and beef produced valued at $4 billion was exported in 2002; 34% valued at $1.5 billion was exported in 2003 as a direct result of border closure following the BSE outbreak in May, 2003 and 35% valued at $2 billion in 2004. Exports rose about 1 % over 2004 to 36 % valued at $1.85 billion in 2005. Canada was the third and fifth largest beef and cattle exporter in the world in 2002 and 2003 respectively (Canadian Cattlemen's Association, 2005).

The beef cattle industry has experienced some consolidation at all levels from cow-calf operations to meat packers. Production is distributed across all the provinces in Canada in unequal proportions. As of January, 2005, Canada produced a total of 15.1 million head of cattle and calves. Alberta as the largest producing province accounted for 68% of Canada fed cattle production, followed by Ontario's 21% production, and Saskatchewan, Manitoba, and British Columbia's combined production of 9%. Quebec and the Atlantic provinces account for about 2% of total Canadian beef production (Canadian Cattlemen's Association, 2005).

There are more than 90,000 reported farms and ranches with beef cattle in Canada, with a beef cow herd of 5.3 million head, concentrated mainly in Western Canada (Statistics Canada, 2005). Most of the herd operations are run by small cattle farms with an average beef cow-herd size of 53 head. 65% of the farms have 24% of the beef cows and each farm has less than 47 cows; 25% of the farms have 36% of the beef cows and each farm has between 47 and 122 cows; and 10% of farms have 40% of the beef cows and each has over 122 cows (Beef Information Centre, 2005). In terms of provincial distribution, Alberta accounts for 39% (2.09 million head), Saskatchewan has 29% (1.54 million head), Manitoba at 13% (670,000 head), Ontario at 8% (421,000 head), B.C at 6% (350,000 head), Quebec at 4% (238,000 head) and the Atlantic provinces at 1% (61,000 head) (Canadian Cattlemen's Association, 2005). In total, Canadian beef production in 2004 was 3.2 billion pounds and consumption was estimated at 2.1 billion pounds that is at 23.4 kg per person per year as against 21.9 kg per person per year in 2003.

Packers' concentration and consolidation has increased in the past twenty years. There are currently 19 federally-inspected beef packers in Canada as against 143 twenty years ago[1], ranging in size from a weekly slaughter capacity of 25 head in Lacombe, Alberta, to 22,000 head in Brooks, Alberta. There are however three major packers that account for about 90% of the total Canadian slaughter capacity- Cargill Foods of High River, Alberta; Lakeside Packers(Tyson) of Brooks, Alberta; and XL Foods of Calgary, Alberta and Moose Jaw, Saskatchewan[2].

The first two plants are U.S. owned multinationals and currently they control together about 60% of total Canadian slaughter capacity, with an approximate capacity of 22,000 head per week each (National Farmers Union, 2005). XL Foods, with its two plants in Moose Jaw and Calgary, is the third largest player in the game with a combined slaughter capacity of 9,000 head per week. Better Beef Ltd. of Ontario, which is the fourth-largest packing plant with a packing capacity of 8,500 weekly nearly matching XL's output, was acquired by Cargill Limited in April of 2005 (National Farmers Union, June 2005).

---

[1] Report on Canadian cattle and beef industry from The Canadian Trade Tribunal , August 1993.

[2] Report of the Auditor General on the Alberta Government's BSE–related assistance programs July 27, 2004

Table 1.1 Canadian Federally Inspected Beef Packers. (2002)

Company	Location	[illegible] processed	[illegible]
Lakeside Packers Ltd (Tyson)	Brooks, Alberta	Steers, heifers, Cows, Bulls	22,000
[illegible]	[illegible], Alberta	[illegible]	[illegible]
XL Beef	Calgary, Alberta	Steers, heifers, Cows, Bulls	5,000
[illegible]	[illegible]	[illegible]	[illegible]
Better Beef Limited	Guelph, Ontario	Steers, Heifers	8,500
[illegible]	[illegible]	[illegible]	[illegible]
Ecolait Ltee	St-Clair Laplaine, QC	Calves	2,400
[illegible]	[illegible], Ontario	[illegible]	[illegible]
Abattoir St-Germain	St-Germain, QC	Calves	1,700
[illegible]	[illegible], Ontario	[illegible]	[illegible]
Bouvry Export Co. Calgary Limited	Fort McLeod, Alberta	Bison	1,200
[illegible]	[illegible], Alberta	[illegible]	[illegible]
Abattoir Z. Billette	St-Louis-Gonzague,QC	Steers, heifers	600
[illegible]	[illegible]	[illegible]	[illegible]
White Veal meat Packers Limited	Weston, Ontario	Calves	250
[illegible]	[illegible]	[illegible]	[illegible]
Pitt Meadows Meats	Pitt Meadows, B.C.	Steers, Cows, Bulls, Calves	75
[illegible]	[illegible], QC	[illegible]	[illegible]
Lacombe Research Centre	Lacombe, Alberta	Steers, heifers, Cows, Bulls	25
Total			

Source: National Farmers Union updated from Canfax Annual Report, George Morris Centre.

A recent look on how the packing/ processing plant sector changed post BSE shows an increase in cattle slaughter capacity for the corporate packers and the extinction and /or abandonment of the small packers. Mergers have increased as in the case of Cargill acquiring Better Beef, and the emergence of a few people's packers most of which are either non-operational or abandoned. Most of the newly emerged packers are new generation coops, or quasi new generation co-operations[3] that use flexible technologies such as hot boning, slower chain speeds, quality/differentiation; team approach to carcass fabrication; traceability; natural/organic beef – large specialty markets; value-added processing; are undergoing a Fordist or Neo-Fordist transition, i.e. a new generation of community-based flexible production (MacLachlan, 2006).

This is in agreement with Steindl's (1976) analysis of imperfect competition. In this analysis, there are cost differences across firms competing in the same industry, implying that firms have different ability to invest and grow through internal accumulation. Steindl argued that this result is a process of competition that evolves from the growth of productive capacity and its interaction with industry demand, and that stagnation occurs when this competition leads to widespread emergence of oligopoly, impeding both further aggressive competition and continued expansion of capacity. Steindl's analysis on imperfect competition explains what is happening in the beef packing industry as presented in the following tables.

---

[3] Co-op with investment characteristics, members own shares which are tradable, shares are delivery rights & obligations e.g. $50,000 for 200 hooks, membership is closed when shares sold reach plant capacity, motivated to integrate supply chain & boost value-added shares expressed in bushels or "hooks" (MacLachlan, 2006).

Table 1.2 Expansions to Canadian Weekly Cattle Slaughter Capacity -Corporate packers

Name	*Location*	*Organization*	*Capacity*	*Status*
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Lakeside Packers	Brooks, AB	Corporation	28,200	Operating
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
XL Beef	Moose Jaw, SK	Corporation	8,000	Operating
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Ryding Regency Meat Packers Ltd.	Toronto	Corporation	1,500	Operating
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Source: MacLachlan *et al* (2006)

Table 1.3 Expansions to Canadian Weekly Cattle Slaughter Capacity.

Name	*Location*	*Organization*	*Capacity*	*Status*
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Peace Country Tender Beef Co-op	Dawson Creek, BC	NGC	500	Pending
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Canadian Premium Meats	Lacombe, AB	Corporate	500	Construction
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Rancher's Own Meat Processors	Edmonton, AB	NGC	4,000	Pending
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Northwest Cattlemen's Alliance	Lethbridge, AB	NGC	10,000	Pending
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Prairie Prime Processing Co-op	Ryley, AB	NGC	2,500	Pending
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Canada Farm Direct	Not Released	Corporate	24,000	Pending
Table 1.3 Cont'd.				
Natural Valley Farms Inc.	Wolseley, SK	[illegible]	[illegible]	[illegible]
Beef Initiative Group	Possibly SK	NGC	7,500	Pending
DMI Food Processors (Canada)	Qu'Appelle, SK	[illegible]	[illegible]	[illegible]
Nesco Meats	Melfort, SK	NGC	1,600	Pending
[illegible] Beef Co-	Dauphin, MB	[illegible]	[illegible]	[illegible]
Natural Prairie Beef	Neepawa, MB	Corporate	1,000	Pending
PRC	Not specified	[illegible]	[illegible]	[illegible]
Atlantic Beef Products	Borden, PEI	NGC	500	Operating

Source: MacLachlan *et al* (2006).

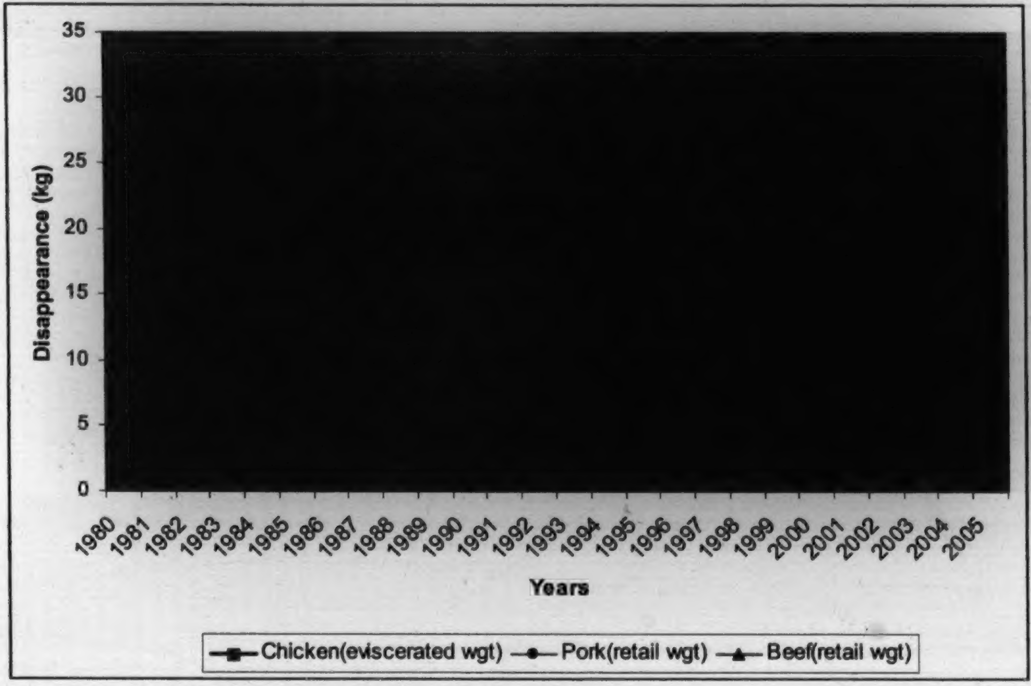
On a global perspective, cattle inventories were about 1 billion in 2002 and 1.1 billion in 2003, with India leading with an average number of head of 318 million and 317 million respectively. Canada was in twelfth place in both years with an average inventory of 13.4 million (1.3%) and 14 million (1.3%) respectively (Beef Information Centre, 2004 & 2005). World beef production was estimated at 49.18 million tonnes in 2002 and 49 million tonnes in 2003 with the U.S leading with 25% and 23.4% market share respectively. Canada ranked tenth in 2002 and eleventh in 2003 contributing 3% and 2% respectively. There was a general decline in 2003 production figures relative to those of 2002 due to the BSE crisis that hit Canada that year and other countries that have been responding to the effect of its outbreak since 1996 in Europe. In the world export market, Australia has maintained leadership with 21% of the world's 7.3 million tonnes exported in 2002 and 19.1% of the world's 7.1 million tonnes in 2003. The U.S exporting 16.5% and 17.1% respectively came second to Australia.

The Canadian beef industry in particular and the world beef industry in general has not existed without a number of daunting challenges, especially since the outbreak of the Bovine Spongiform Encephalopathy (BSE) in the 1980s and its link to human health identified in 1996 in Europe, and its subsequent discovery in May of 2003 in Canada.

Many of these revolve around economic and social issues (Lomeli, 2005). The beef industry has faced challenges of declining consumption over the past two decades, which was exacerbated by the BSE incidence in Northern Alberta of May, 2003, closing international markets contributing to plummeting producer prices. However, packers' profit margins have been increasing in the past two decades possibly due to an increase in concentration and consolidation. Mason's draft report to the public accounts committee of the Alberta Beef Industry Council states: "The average packer gross margin for the period of Sept. 22, 2003 to Feb. 16, 2004 is $431 per carcass. This compares to $144 per head-one year ago and to $208 per head (Canadian dollars) for the U.S. during the same time period. In other words, packers' margins are 200% higher than one year ago and 107% higher what is currently the case in the U.S". This led to the Auditor General's report that states that packers' gross margins increased to 281% during and after the BSE crisis due to a distorted market in which cattle supply significantly exceeded slaughter capacity and domestic consumers maintained the demand for their production (Alberta Auditor General Report, 2004).

As seen in figure 1.1, in Canada, per capita beef consumption has declined significantly over the past two decades, with a mean value of between 38 and 39 kg per capita per year in the 1980's and between 29 and 30 kg per capita per year in the past decade (AAFC, 2005). The increasing per capita chicken consumption (about 90%) and an accompanying relatively constant pork consumption has maintained overall per capita meat consumption at 90 kg over the past two decades. The changing consumption pattern for meat, from red meat to poultry, was partly due to increasing health concerns around saturated fats and consequent diseases as evident in Canada. The National Institute of Nutrition on Tracking Nutrition Trends (2002) concluded that Canadians expressed increased concerns about saturated fat, cholesterol, sugar, trans-fatty acids and caffeine in diets. Recommendations made by the Canada's Food Guide to Healthy Eating and other nutritional information and perceptions have had a long term effect on the beef consumption and a resulting increase in white meats consumption. The BSE era in Canada saw declining producer prices due to the closure of the border but per capita consumption increased within these two years from 21.9 kg to 22.4 kg yearly (Beef Information Centre, 2003 & 2004).

Figure 1.1 Per Capita Disappearance of Beef, Pork and Chicken in Canada (1980-2005)

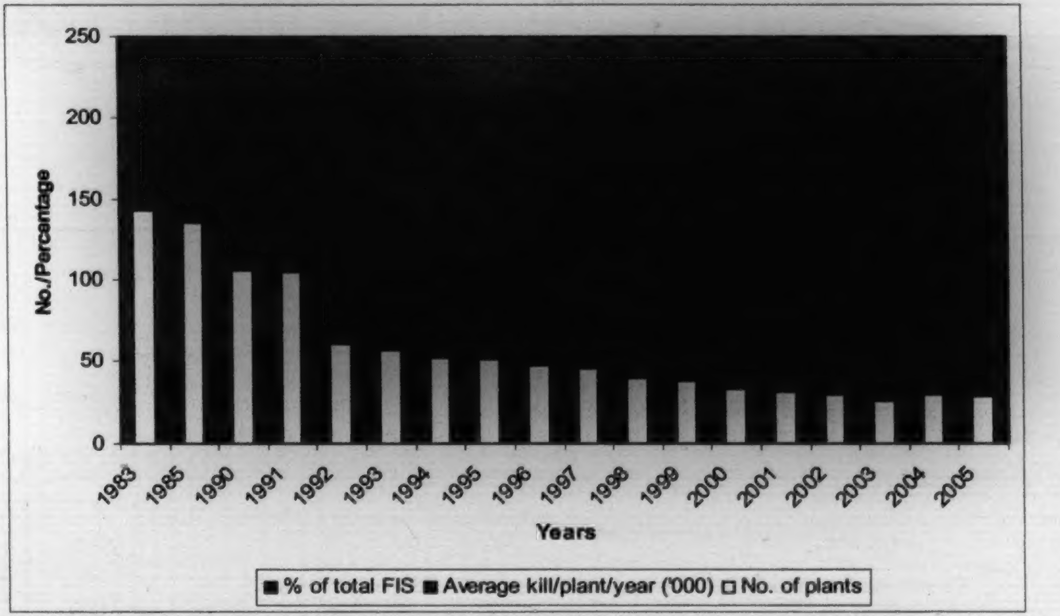


Source: Statistics Canada, Cansim Table # 0020011.

Despite the fact that the BSE outbreak in 2003 made most of Canada's trading partners close their borders to imports, especially its major partner the U.S. who had imported about 60% of Canadian beef, Canadians consumed 5% more beef in 2003 as compared to 2002. Cattle producers are the ones affected by this outbreak as they have recorded declining prices.

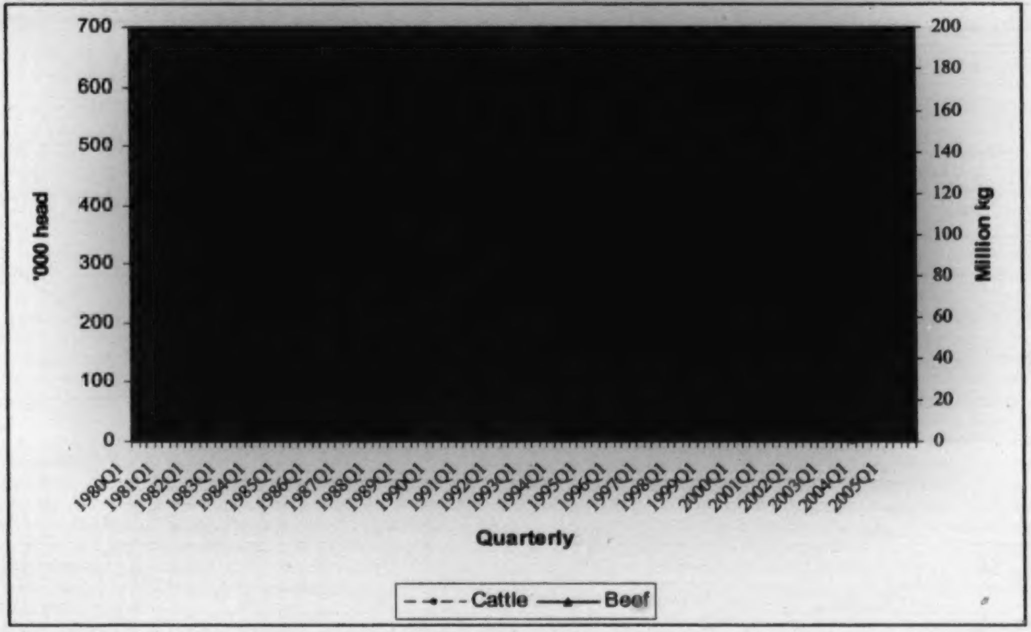
When the U.S. and other Canadian beef exporting countries borders suddenly closed in May, 2003, the livestock industry was thrown into chaos. In September 2003, the big packers were able to resume export of boxed beef into the lucrative U.S. and other international markets; even though live cattle exports were prohibited. However, cattle prices declined while export and retail beef prices continued to rise. Figures 1.2-1.7 below summarized the situation in the beef industry as regards producers, beef packers consolidation and the BSE shock within Canada, and between Canada and the U.S.

Figure 1.2 Distribution of cattle slaughtering activity and the top 4 federally inspected slaughter (FIS) plants market share in Canada (1983-2005)



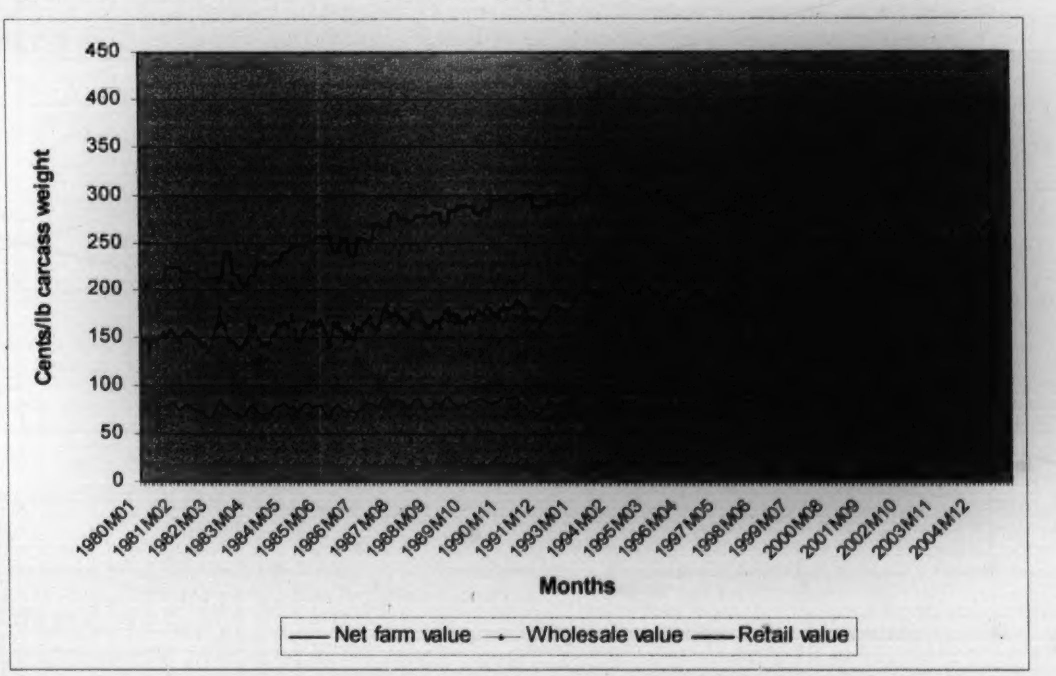
Source: Agriculture and Agri-Food Canada, Cattle Slaughter Statistics for Federal Abattoirs and Canadian International Trade Tribunal Report on Canadian Cattle and Beef Industry.

Figure 1.3 Canadian Cattle and Beef Exports (1980-2005)



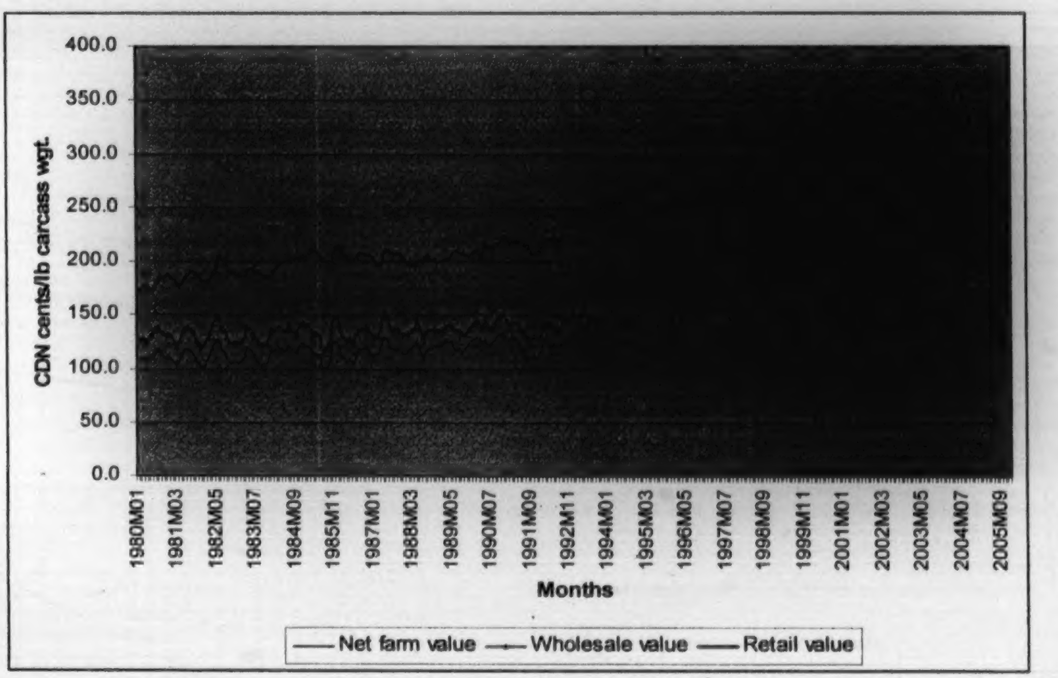
Source: Canada Livestock and Meat Trade Report, CANFAX and AAFC website.

Figure 1.4 Farm, Wholesale and Retail Prices of Beef in Western Canada 1980-2005



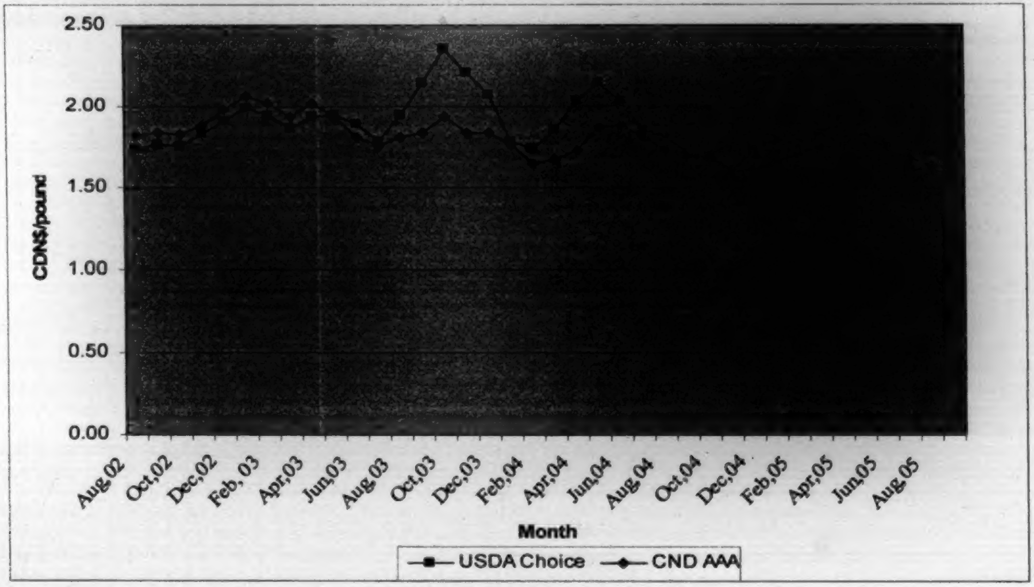
Source: Generated from different issues of the Canada Livestock and Meat Trade Report

Figure 1.5 Farm, Packer, and Retail Prices of Beef (Steers) in the U.S. 1980-2005



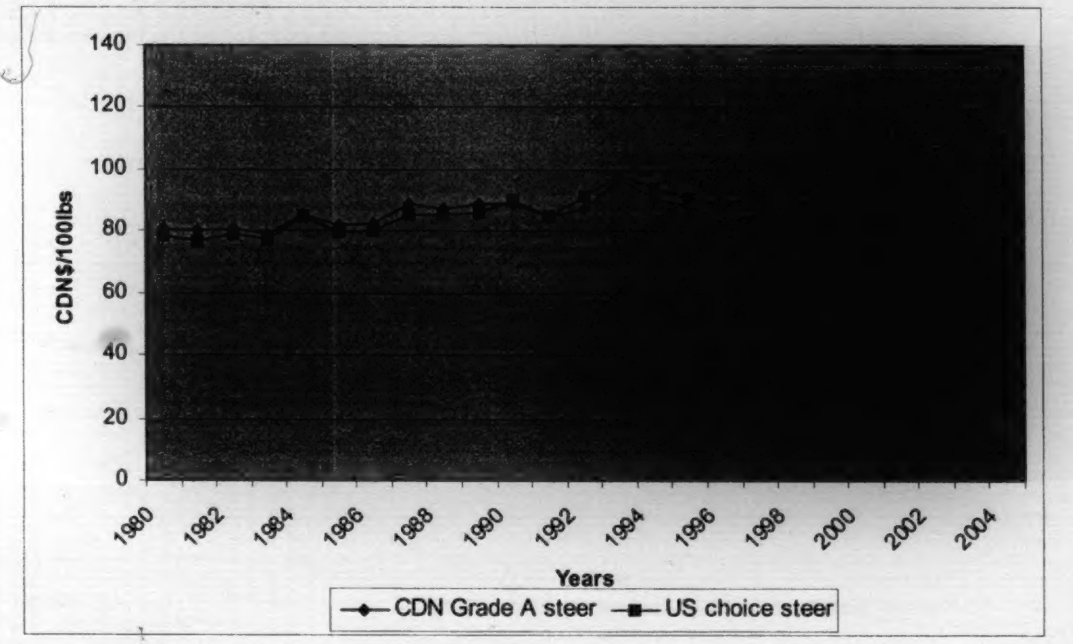
Source: Generated from the 2006, ERS, USDA Red Meat Yearbook Report Stock# 94006

Figure 1.6 Monthly Boxed Beef Prices for U.S. and Canada (Aug. 2002- Sept. 2005)



Source: CANFAX Weekly Summary, 2002-2005.

Figure 1.7 Weighted Average Prices of Cattle Between the U.S. and Canada (1980-2004)



Source: Agriculture & Agri-Food Canada Annual Livestock and Meat Trade Report, 1980-2004.

The beef industry is structured with a number of different levels that move beef from "farm gate to plate". These levels are the cow-calf operations, the backgrounding phase, the feedlot operations, the packers, retailers and finally, the consumers.

The first stage in beef production is the cow-calf operation in which calves are raised for the beef industry. Cows selected for mating in early summer are picked based on their mothering ability, beef quality and other desirable genetic traits. Calving starts toward the end of winter and attain its peak during the spring of the following year. The entire cow-calf process take place exclusively outside on open pasture on most farms, where the cattle graze and calves are nursed until they attain a weight of about 500-600 pounds. After weaning, calves are sent to the backgrounding operations where they are over-wintered outdoors on a forage-based diet, sometimes this occurs on the cow-calf farm (Canadian Cattlemen's Association and Beef Information Centre, 2005).

At the backgrounding operations, calves are over-wintered on hay-based diets until they attain a weight of about 900 pounds. At this stage, the animals are sheltered and bedding areas provided for comfort and protection. They are then sent to the feedlots where intensive conventional beef production takes place until they reach finished weight. On a feedlot, beef production begins with a diet made up of forages and progressively moves to about 90% grain to produce tender, marbled beef. Cattle are fed on these diets for about 60-120 days before they are sold to the processors/packers (Canadian Cattlemen's Association and Beef Information Centre, 2005).

The processors/packers are the slaughter houses where these animals are slaughtered and processed into cuts and packaged and sold as boxed beef to wholesalers and/or retailers, who either sell them to consumers as packaged by the processors or repack them for consumers' convenience.

The Canadian Beef Grading Regulations assess carcasses on quality and yields after being subjected to stringent requirements for health and safety by a Federal or Provincial inspection program. There are 13 grades of the Canadian beef carcass grading based on assessment of carcass maturity, sex, muscling, meat quality, external fat covering and marbling.

These grades are:

- Canada A, Canada AA, Canada AAA, Canada Prime
- Canada B1, Canada B2, Canada B3, Canada B4
- Canada D1, Canada D2, Canada D3, Canada D4
- Canada E

The first grade category is the highest quality grades and represents 93 per cent of all Canadian graded beef in 2004 (Canadian Cattlemen's Association, 2005). Grades Canada A and higher grades are subjected to lean meat content or yield of carcass grading. Fat score and carcass muscle score are the two major yardstick used for estimating yield.

There are three possible yield grades of beef in Canada as follows:

- Carcasses estimated to contain 59 per cent or more lean meat are designated yield classification Canada 1;
- Carcasses estimated to contain between 54 and 58 per cent lean meat are designated yield classification Canada 2;
- Carcasses estimated to contain 53 per cent or less meat are designated yield classification Canada 3.

1.3 Economic Problem

The beef industry has been subjected to inquiries[4] and studies investigating its structure and conduct because of alleged actions of unfair market power. This problem dates back as far as 1979 when prices of retail cuts of beef and pork rose thirty to forty percent from a year earlier and farm prices did not increase by that percentage, therefore raising interest in pricing behaviour (1979 commission of inquiry report into the marketing of beef and veal). Over the past two decades, the open border and the integration of the North America beef sector has meant fewer buyers due to intense concentration. This is further aggravated in the Canadian context due to the overdependence of the Canadian beef industry on the lucrative U.S. export market (see figure 1.8 below). Packers own a number of cattle on feed in various custom feedlots around Canada and there is no law controlling packer ownership of cattle. The major packers are vertically integrated into feedlot operations, with packer-owned cattle procurement, for example in Alberta averaging 16% of cattle marketed in the past six years (Alberta Auditor General Report, 2004). This is evident in the Alberta Auditor General Report, which stated that the BSE compensation programmes paid at least $45 million (Cargill $9 million, Tyson $33 million and XL Foods Inc. $3 million) to the three major packers in Alberta as owners of cattle (Alberta Auditor General's report, 2003-2004). Partial vertical integration provides a more secure and balanced supply of fed cattle to their plants throughout the year, hence lowering their investment risk while realizing greater economies of scale.

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[4] Reports such as: The final report on financial analysis relative to meat packing companies in the context of the BSE crisis of 2003; Report of the Auditor General on the Alberta government's BSE-related assistance programs; The Food Prices Review Board reports and the 1976 *Commission of Inquiry into the Marketing of Beef and Veal,etc.*

The profit margin for cattle production has been falling for the last decade and exhibited a further meltdown after the BSE crisis. Historical data from Canfax statistics shows that a decade ago, the accepted net return on average for beef cows in Western Canada was $175 to $200, which declined to between $50 and $125 in the two years prior to the BSE crisis. Meanwhile packers' gross profit per head rose from about $75 to about $210. This trend has profited the packers who get a steady supply of cheap animals, but bad for farmers who face increased operating costs and lower returns.

CANFAX report of June 2004 revealed this wealth extraction situation. When fat cattle worth 72 Canadian cents at the farm gate in Canada are processed and exported into the U.S. market, they are sold in grocery stores alongside processed beef that return the equivalent of $1.19 Canadian dollars. The level of corporate concentration has led to the attribution of lower prices and loss of price transparency in Canada, to packer ownership and captive contracting with large feedlots and packers fed- cattle ownership in the Canadian market.

Beef sales have traditionally given processors a profitable business that has been very attractive to multinational firms that have consolidated into fewer firms. Perceptions arising from this trend are that of reduced welfare of farmers, through lower cattle prices than would have prevailed in a competitive environment devoid of the nature of consolidation experienced by processing plants. The U.S. too has had the same situation of consolidation of packers.

The possible existence of market power in both input and output markets, involving potential for excess markups of output prices and markdown of input prices than would have existed in a competitive scenario has been raised (Morrison, 2000). This is attributed to the market structure and concentration in the beef industry. However, reports[5] from the Federal Competition Bureau of Canada (FCB) seem not to confirm these concerns. It suggests that concentration and consolidation could have been caused by efficiency gains from cost of production management and greater productivity and not necessarily market power. Contrary to the FCB report, studies done in Canada consisting of Beck and Mozejko (1992), Liu (1991), Cranfield (1995), Cranfield and Goddard (1999), Druhan (1992), Quagrainie (2003); Zhou (1991) and Unterschultz et al (1997) have so far reported the presence of market power in the beef industry. Approaches used in these studies however have been the usual tests of market power based on the deviation between marginal cost and price using the structure-conduct-performance and intra-industry method. These have been shown to be misleading because they do not fully take into account the cost economies and efficiency gains (Morrison, 2001b). Therefore, incorporating the concept of marginal cost and average cost to account for the effect of cost economies will be important, for accurate estimation and interpretation of market power and implications for consumers and farmers welfare. This is however not without complication in terms of measurement and estimation of the structure, conduct and costs components of the industry.

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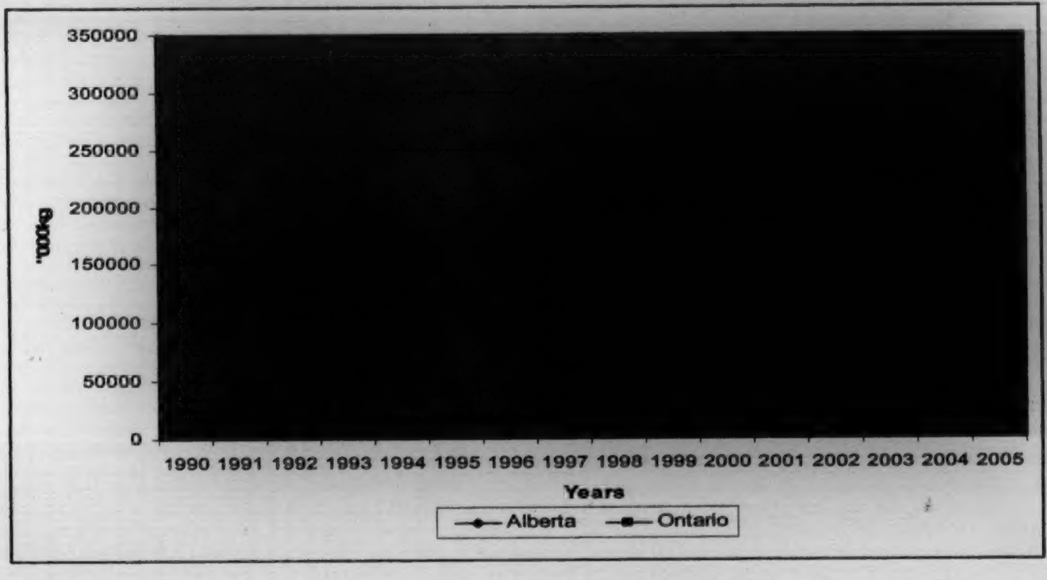
[5] An Investigation of the Effects of BSE on the Canadian Cattle and Beef Markets and A Time Series Analysis of Canadian Cattle and Beef Prices and Quantities Prior To and Following the May 2003 Discovery of BSE in the Canadian Cattle Herd by Drs. Love and Bessler, 2005.

Figure 1.8 Alberta and Ontario Provincial Beef Exports into the U.S. (1990-2005)



Source: Statistics Canada Provincial Beef Export Data, CANSIM II.

1.4 Research Objectives:

Studies of market power and price asymmetry in the beef industry in Canada were conducted in the 1990's[6] using the New Empirical Industrial Organization methodologies without the inclusion of cost economies, which makes it imperative for a similar study to be undertaken under current scenarios.

Similar studies conducted in the United States[7] discovered some level of cost economies and high level of market power due to concentration and consolidation of packers in the beef industry. Although Canada and the U.S. share the same open border and price determination mechanism, the Canadian beef industry has been distinct from the U.S. since the BSE crisis because of the incidence of BSE and its accompanying trade implications.

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[6] Studies such as Beck and Mozejko (1992), Liu (1991), Cranfield and Goddard (1999), Druhan (1992), Zhou (1991)and Quagrainie (2003).

[7] Studies notably include: (Azzam and Schroeter 1991; Azzam and Shroeter 1995)(Azzam 1997), (Morrison 1999; Morrison 2000), (Schroeter 1988).

The purpose of this study is to identify the economic determinants of production and processing, consumption and trade of the North America beef and cattle production. This will be done allowing for the determination of the degree of market power, or lack thereof, in the beef industry by using a modified North American beef model drawn from Cranfield (1995) to estimate the degree of non-competitiveness of firm conduct and the degree of and sources (cost efficiency or collusive market power) of oligopoly/oligopsony power in the Canadian and North American beef industry. To this end, it is important to develop models in which inferences on the nature of firm conduct, and both the sources and degree of oligopoly/oligopsony power can be estimated using regional industry data.

The major goal of this study is to provide an analysis of the market structure in the beef industry with specific interest on the processors of value-added meats and retailers; the pricing methods involved between the backgrounders/feedlots and the processors; and the presence of, or lack of, cost economies and market power as a result of concentration and consolidation in the industry.

The specific research objectives for this study are to use calculated farm, wholesale and retail data, and beef processors industry data to:

1. Analyze the market structure in beef processing and retailing econometrically.
2. Determine the price-cost margins between the backgrounder/feedlots and processors, and cost economies.
3. Using simulation of the estimated model to examine the welfare impacts of BSE in terms of producer and consumer surplus and processor profit.

Critical empirical analyses of price-cost margins (market power) will be undertaken by developing econometric models based on the market power literature. The models will be simulated, under different assumed market conditions, to show the effects of BSE. Previous literature on market power in the beef industry in North America and some European countries will be reviewed and compared. The price-cost margin analysis will be estimated before and during the BSE crisis in western and eastern Canada and a Canadian market aggregate analysis will be undertaken. The North American beef model will also be used to examine the economic impact of BSE related border closings, by simulation using trade quantity shocks to show the effect of border closure on trade.

With few studies in the Canadian context recently, this study will contribute to answering some questions about an industry of economic importance to Canada, and could enhance policy formation that might influence local and international demand for beef in Canada.

1.5 Organization of the Study:

In chapter two an overview of the impact of BSE in Canada and some of it's economic consequences is provided. Different analytical techniques are also reviewed in order to select an appropriate technique for this study. A conceptual framework is developed and the data acquisition process is presented in chapter three.

A full empirical exposition of the model, data and estimations carried out are presented in chapter four and results of empirical analysis are presented in chapter five, and these are further summarized and discussed in the conclusions in chapter six. Possible policy implications, limitations of this study, and recommendations for areas of further research form the conclusion of chapter six.

Chapter Two: LITERATURE REVIEW

In line with the objectives of this thesis, the impact of trade regulations and restrictions and their effect on the structure of the beef industry is examined in this chapter. Some of those regulations and policies imposed by governments have had influence on the structure of the industry; therefore, this chapter tries to algebraically and graphically examine these effects both for an assumed perfectly competitive industry and one that is non-competitive. Following this, econometric models of market structure and market power will be reviewed in other to develop a conceptual and empirical model to be used in achieving the research objectives. An overview of BSE in Canada is provided followed by an exposition of the North American beef models. The last part of this chapter will contain a summary of the entire chapter and what this study intends to do in an effort to answer the research questions drawing from the literatures reviewed.

2.1 Background

Recent increases in aggregate concentration in Canada have stimulated interest in measuring the degree of oligopoly or oligopsony market power considering the fact that broad measures of aggregate concentration, especially in the beef sector, have shown increasing trends in the later part of the twentieth century (Jones et.al, 1996). Steindl (1952) argues that in an economy devoid of exogenous interventions, either from government regulations or disaster, what drives the process of transition from one market structure to another are notably: technical change, pricing behaviours and capacity utilization. Steindl sees increased investment in capital bringing about a technical change that confers a cost advantage on firms that both choose to and are able to adopt it; which consequently increases the levels of capacity utilization and concentration. This advantage makes firms either want to be price takers (perfectly competitive) or price makers (monopolies/monopsonies or oligopolies/oligopolies). However, with exogeneous interventions from the BSE crisis and the several interventions of government, the reason for a changing market structure goes beyond Steindl postulation.

2.2 Bovine Spongiform Encephalopathy (BSE)

BSE, also known as "mad cow disease," is a progressive, fatal disease of the central nervous system of cattle, which has been linked with the fatal human neurological condition variant Creutzfeld-Jacob Disease (vCJD). The disease, also considered as a Transmissible Spongiform Encephalopathy (TSE), was first confirmed in southern England in December 1986. Following the initial diagnosis in the UK, there had been 180,903 BSE cases and 1,924 cases reported in the UK and elsewhere in the European Union (EU) (Lomeli, 2005). At this point, the record high had been a yearly peak of 37,280 confirmed cases in 1992 in Great Britain.

Although the origin of BSE in cattle remains unconfirmed, the epidemic in the U.K. is believed to have resulted from feeding cattle meat and bone meal (rendered ruminant protein) containing the tissues of BSE-infected animals, beginning in the 1970s. Several factors may have combined to produce the epidemic, including changes to the rendering process in the U.K. and the increased use of meat and bone meal in calf feed in the years preceding the outbreak. There is no evidence to indicate that BSE is a contagious disease.

vCJD was first diagnosed in the U.K. in 1996 and scientific evidence now indicates that vCJD is caused by the same agent that causes BSE in cattle. Prior to 1996, it was not believed that BSE could be naturally transmitted from cattle to humans as such, this finding was significant in the study of this disease. It is widely believed that the human cases of vCJD globally are the result of eating cattle tissues infected with the BSE agent.

The BSE outbreak in September of 2001 in Japan, the largest Asiatic beef importer, was the first Asiatic case, and as of 2004, there had been eight reported cases in Japan. This led to a mandatory BSE testing for every single animal slaughtered in Japan or imported, which was viewed as a protectionist trade strategy. They have however reduced this strict trade regulation and most of their trade partners, like the U.S. and Canada, can now export beef and beef products from animals less than 20 months to Japan (CFIA, 2005).

A popular hypothesis is that BSE entered North America during the 1980s when Canada and the United States imported a limited number of cattle from the U.K. With long incubation period of the disease, chances are that some of the cattle would have been infected with the disease when imported despite appearing healthy. Canada actually started importing U.K.s cattle in 1982 and the last year that UK's import effectively entered Canada was 1989.

Between May 2003, when the first single North American BSE case was found, and May 2007, there have been ten cases of BSE detected in cattle born in Canada, comprising seven raised in Northern Alberta, two in the province of British Columbia, one case of a cow raised in Washington State, US. Immediately after the first case in Alberta, Canada, importing countries banned the importation of Canadian cattle, beef and beef products, which consequently affected the Canada's export oriented beef industry. The US and Mexico however opened their border to some Canadian beef products three months later after May 20, 2003. The US border was finally opened to live cattle after the ruling of the ninth circuit court in July 2005, which led to many other trading partner nations lifting their ban on Canadian beef and beef products.

Table 2.3 presents a summary of the BSE crisis and the market conditions that followed every event until May of 2007.

Table 2.1 Main chronological events related to the Canadian BSE case

Date	Events and Market developments
1986	*BSE was first documented in the United Kingdom (UK)*
1990	*BSE was designated a reportable disease under the Health of Animals Act in Canada. Canada places UK origin cattle under an animal health monitoring program.*
1992	*The National BSE surveillance program was implemented*
1993	*A cow imported from the UK that was in the monitoring program initiated in 1990 was confirmed infected with BSE*
1994	*The remaining UK cattle imports either returned to the UK, or were euthanized after been tested negative for BSE*
1997	*Canada and US responded to the WHO recommendations on precautionary measures by implementing their respective mammalian protein feed bans. That Canada Feed Inspection Program was expand to include the mammalian-to-ruminant feed ban regulations targeting manufacturers and retailers of feed, and farms to ensure compliance with the regulations.*

2001	*Canada initiated the Cattle Identification program to enhance their ability to trace individual animals from the herd of origin to slaughter*
January 31, 2003	*An 8-year downer is slaughtered in a provincially inspected abattoir in Alberta. The carcass is condemned due to a finding of pneumonia. Samples are sent to the provincial laboratory for a routine BSE test, not considered a priority as the carcass was rendered into animal feed.*
May 16-20, 2003 *diagnosis*	*The provincial laboratory in Alberta makes a preliminary of BSE. Two days later The Canadian Food Inspection Agency (CFIA) and the Veterinary Laboratories Agency in Weighbridge, Surrey, UK –the world reference lab for BSE testing- are asked to conduct confirmatory tests. Both labs confirm a BSE-positive result on May 20th.*
May 20, 2003	*The BSE finding is officially announced. CFIA contacts Canada's trading partners, and the Office International des Epizooties (OIE), industry associations, and provincial partners.*
May 21, 2003	*Border closure by US, Mexico Japan and Korea. The Canadian Cattlemen's Association (CAA) notes that "this was an isolated incident and the surveillance system worked to prevent the infected animal from entering the human food chain".*
May-November	*At the news of a BSE case in Canada, US live cattle futures close sharply lower. They bottom out in mid 2003 June then rally highs around US$100/cwt in November.*
May 26, 2003	*The CFIA declares that Alberta's herd is disease-free. Canadian live cattle markets remain closed. Packers suffer significant losses on beef export contracts and product already in transit to export markets. Live cattle prices in Alberta drop from C$2.4/kg in early May to C$1.8 once they reopen in late May and to C$1/kg by the end of June. They will bottom at C$0.70 in late July.*
June 18, 2003	*The federal-provincial government announces the Canada Alberta BSE Recovery Program. The plan pays producers 90% of the difference between US and Canadian average weekly live cattle prices, up to maximum of 50% of the US price. Packers are to be compensated to move products currently clogging their plants. Fat cattle rushed to market, depressing prices. Alberta packers increase weekly kill from 18,000 hd/wk to 40,000 hd/wk, close to the pre-May 20th level.*
July 24, 2003	*A CFIA directive requires the removal of Specific Risk Materials (SRM) from slaughtered cattle in federally registered establishments.3 Packers incur additional disposal costs. The Canadian Health of Animals regulations and the Food and drug regulations were amended to remove Specified Risk Material (SRM) from the human food supply.*

July 25, 2003	*In order to alleviate the flood of cattle sales, Alberta offers to compensate producers who agree to delay marketing for 8 weeks. Payment is as per the previously announced federal plan.[1] A Loan Guarantees/Disaster Assistance Loans (AFDL) provides a short-term cash flow relief. The Stranded Export Beef Container Initiative (SEBCI) provides financial compensation to foreign buyer for storage and demurrage costs that has been rejected in transit or held in bonded warehouses in foreign markets. 3 SRM are defined as the skull, brain, trigeminal ganglia (nerves attached to the brain), eyes, tonsils, spinal cord and dorsal root ganglia (nerves attached to the spinal cord) of cattle aged 30 months or older, and the distal ileum (portion of the small intestine) of cattle of all ages.*
August 5, 2003	*Japan requires US to certify starting on Sept. 1 the absence of Canadian beef in shipments of U.S. beef to Japan (original deadline of July 1st is extended to September 1st to allow definition of practical aspects of this certification). In Canada this is seen as a possible further delay of the opening of the US border.*
August 8, 2003	*US opens border to Canadian boneless beef from cattle under 30 months. Positive reactions in Canada. Slaughtering capacity constraint prevents Canadian industry from taking advantage of opportunity. Mexico opens three days later. The president of the CCA comments that this is a big step for re-establishing an integrated North America beef market.*
August 17, 2003	*CCA calls for additional relief, such as interest-free advances and cash settlement for cattlemen who had not yet received the previously announced compensation; also calls for new industry standards and procedures to identify cattle less than 30 months*
September, 2003	*Animal over 30 months remains essentially worthless as limited slaughtering capacity in Canada provides an incentive not to process these animals. Industry scrambling for solutions. The Beef Industry Value Chain Round Table in Calgary suggests their employment as raw materials for processed beef products. CCA lobbies for extension of Canada's decision to suspend supplementary imports of off-shore beef.*
September 10, 2003	*The first shipment of Canadian boneless products from cattle under 30 months old gets in US. However, trade is hindered by complex paperwork.*
November 21, 2003	*The federal government announces the Canada Cull Animal Program, with a federal payment of C$912/hd. CCA is concerned plan is ineffective for animals over 30 months. The requirement to cull cows to receive the payment is removed in mid-February.*
December 23, 2003	*The USDA announces a possible case of BSE in Washington State.*

December 24, 2003	*Canada bans beef imports from US. A similar restriction applies to US pet food. The consensus is that this will delay the resolution of the crisis and the opening of the US border to Canadian cattle.*
January 6, 2004	*DNA test indicates that ill cow found in Washington State was born in Canada.*
January 7, 2004	*Canadian pet retailers and distributors of pet foods raise concerns about pet food availability in Canada as a large percentage is imported from the US. Canada also announced enhanced surveillance programme.*
March 4, 2004	*USDA extends to April 7th the comment period on the proposed opening of imports of live cattle under 30 month and bone-in beef into the US.*
April 19, 2004	*All Canadian beef products from cattle under 30 months older can enter in the US.*
January 2, 2005	*Another BSE case (number three) was confirmed in indigenous Canadian cattle from Alberta.*
January 11, 2005	*Case number four of BSE was confirmed in Canadian Indigenous cattle from Alberta.*
Fall, 2005	*Proposal to strengthen the animal feeding ban was finalized in Canada after extensive consultation with provinces and industry stakeholders.*
December, 2005	*In other to be in tandem with current international guidelines, Canada implemented a revision of its BSE import policy*
January 11, 2006	*The fifth case of BSE was detected in Alberta, Canada.*
April 13, 2006	*The sixth case of BSE was found in a British Columbia cow*
July 2, 2006	*The seventh case of BSE was found in a dairy cow on a farm in Northern Alberta.*
August 09, 2006	*The eighth case of BSE was detected in a commercial beef cow on a farm in Northern Alberta, Canada.*
January 22, 2007	*The ninth case of BSE was found in a bull on a commercial farm in Northern Alberta following the loss of body condition over the winter.*
May 2, 2007	*The tenth case of BSE was found in a mature dairy cow on a farm in British Columbia.*

Sources: AAFC; CFIA; and Statistic Canada, 2005.

The global beef/cattle industry has undergone structural change in terms of consumption and trade since the first reported BSE case in Europe in 1996. This has affected the market structure of this industry due to different policy interventions from governments and industries alike that ranges from trade regulations, assistance programs to farmers and processors, and increased food safety regulations which have generated increased costs in processing. The North American beef industry has not yet returned to its pre-BSE state after the first BSE case in Alberta, Canada in May of 2003. Though the industry had been concentrated prior to BSE, the effect of the disease and subsequent government interventions re-modified the industry in terms of pricing behaviour and trade. Before we go further, a look at the economics of government regulatory strategy and actions, and their implications on the structure of the beef industry is discussed.

2.2.1 Trade Barriers

Following the introduction of free trade agreements, Canada has enjoyed export markets in cattle and in beef so much that in 2001, it held about 15% of the world beef market, ranking in third place only next to the United States and Australia[8]. Prior to May 20, 2003, about half of the cattle produced in Canada were exported as either live animals or meat. However, this trend changed suddenly after the first case of BSE in Alberta, Canada which resulted in a ban on Canadian cattle and beef products into the US and other major importing countries. The US-Canada border was closed to all beef cuts and live cattle following the discovery of the first case in Alberta, Canada in May of 2003.

The integrated North American cattle/beef industry, evolved over the last 20 years undertakes relatively free trade in beef and cattle where prices would equilibrate across borders, the only difference being transportation costs *ceteries paribus*. Since about 60% of the Canadian cattle and beef production is exported, mostly into the U.S. (Beef Information Centre, 2005), any distortion in trade is expected to affect the market in terms of competition and pricing behaviour. With the closure of the border to Canadian beef and cattle in May 2003 and its reopening in September, 2003 to only beef from cattle below thirty months of age, the possibility is for processors/retailers to exercise market power at both the input and output levels. Some recent studies[9] suggested that meat processors and retailers conduct is consistent with oligopolistic and oligopsonistic market power in output markets and at the farm level. The export ban following BSE created excess supply relative to demand firstly, for both cattle and beef supply for the first three months of the crisis then second, to only cattle supply until June of 2005 when the ninth circuit court ruled in favour of allowing Canadian cattle below thirty months of age to move across the border. These events saw plummeting prices at the farm level supply of cattle but the demand for retailed beef and beef products had little or no change so much so that, beef consumption increased in 2004 (Statistics Canada). We expect that there will be structural breaks in the relationship between the producer, wholesale and retail prices due to the trade restrictions due to BSE as found in Sanjuan and Dawson (2003) in the UK meat sector.

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[8] Reported by Agricultural and Agrifood Canada , taken from Canfax statistical briefer, 2005.

[9] Morgan and McCorriston (2005); Anders (2005); Lopez, Azzam, and Liron-Espana (2002); Koontz, Garcia, and Hudson (1993) Koontz and Garcia (1997); Schroeter and Azzam (1990); Schroeter (1988).

Table 2.2. Canadian Trade Restrictions and Regulations-Pre and Post BSE

Date	*Trade Restriction/Regulation*	*Against/In-favour*
1978	Canada prohibits the import of meat and bone meal (MBM) due to concerns about Foot and Mouth and other priority diseases to livestock	Other countries with the exception of the U.S.
1982-1990	Canada imported cattle	The United Kingdom
1986	The Importation of meat meal, bone meal and blood meal were officially banned	Globally except the U.S.
1990	Canada prohibited further importation of cattle with the total of 191 animals already imported during the period 1982-1990	The United Kingdom
1996	World Health Organization (WHO) recommendation that feed bans be implemented	All member countries
1997	Implementation of the mammalian protein feed ban(with some exceptions) as a precautionary measure in response to WHO recommendations	Canada and the United States
2000	Canadian Food Inspection Agency (CFIA) suspended the importation of all rendered animal protein products, of any species.	Any country not recognized as free of BSE
May 21, 2003	Border closure by US, Mexico Japan and Korea to cattle and beef	Canada
August 8, 2003	US opens border to boneless beef from cattle under 30 months. Slaughtering capacity constraint remain a problem in Canada. Mexico opens three days later	Canada
December, 2003	CFIA imposes an import regulation for a range of animals, their products and by-products due to a case of BSE detected in Washington State	The United States
April 19, 2004	All beef products from cattle under 30 months old can enter into the US	Canada
July 9, 2005	New Zealand lifts their remaining BSE-related restricted effective immediately	Canada
July 18, 2005	Livestock began to cross the U.S. border for feeding and slaughtering after the ninth circuit court of appeal ruling	Canada
Dec. 11, 2005	Japan lifted ban on beef and selected beef products from cattle20 months or younger	Canada
December, 2005	Import prohibition of ruminant derived meat and bone meal or greaves, or any commodities containing such products into Canada, unless a risk assessment has been undertaken and country classified in the negligible BSE-risk category	All countries
January12, 2006	Only animals confirmed not pregnant are eligible for export under the US Minimum Risk Rule	Canada

Source: CFIA (www.inspection.gc.ca), AAFC (www.agr.gc.ca), 2005.

2.2.2 Increased Costs

Before and following these BSE cases, the federal and provincial governments of Canada have put in place BSE safeguard measures to help prevent and ameliorate the risks of BSE spread in Canada as will be seen in table 2.2. These safeguards are: specified Risk Material (SRM)[10] removal, feed Ban Regulations (FBR), import policies and surveillance and animal tracking (SAT). These policies however came with the burden of increased costs to the farmers, processors and retailers which affected the competition and price setting mechanism in the beef industry as well. This affected farmers in terms of increased cost of feed inputs as meat and bone meal materials were prohibited from animal feed. As for the processors, increased cost came as a result of the removal of all specified risk materials from every carcass processed, that is a per head cost. All three marketing participants have to also maintain costly food safety regulations in order to maintain constant hygiene.

From the theory of the firm, increased cost reduces profit to the point of zero or negative value unless there is either a corresponding and commensurate increase in output (beef) price or a decrease in input (cattle) price, or both (Lloyd et al. 2006); Stern (1987); Dixit (1986). However, from the Report of the Auditor General of Alberta in 2004, the packing plants increased profit (281%) and slaughter cattle prices plummeted. This is indicative of increased profit via decreased input prices. Strategically, pricing behaviour changed in this industry that was already concentrated and this affected the structure of the market. Gardner (1975) showed that increasing marketing costs say from the SRMs regulations, leads to a rise in price spreads so does any supply shock that reduces producer price. McCorriston, Morgan, and Rayner (1998); McCorriston, Morgan, and Rayner (2001) found causality between the increased price spread following a shock (BSE) in the downstream food sector and imperfect competition. Therefore exogenous shocks such as increased cost may have a tendency of affecting the market structure.

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[10] SRMs are the infected tissues that contain the agent that transmit BSE in infected cattle. These tissues have a high concentration of the infective agent and include the skull, eyes, tonsils, brain, trigeminal ganglia (nerves attached to the brain), spinal cord and dorsal root ganglia (nerves attached to the spinal cord) of cattle aged 30 months or older; and the distal ileum (portion of the small intestine) of cattle of all ages (CFIA, 2005).

2.2.3 Government Assisted Programs and Subsidies

Another policy intervention that affected the market structure is the government subsidies and other assisted programs put in to help absorb devastating effects of BSE. In an interim report on Canadian cattle slaughter capacity presented on May 19, 2004, the federal government was urged to support the growth of the meat packing industry through financial assistance programs for new packing plants and expansions, or for producer owned, new plant start-ups through cooperative investments.

The recommendations of this report are:

- government should enhance the existing Loan Loss Reserve program with a capital matching program to address the need for start up capital;
- government should develop new tax incentives for investment, including a cooperative investment plan that would provide a tax credit for individuals investing in cooperatives;
- government should expand the eligibility of existing programs to producers or producer groups wishing to acquire packing facilities even if the acquisition does not immediately result in an increase in slaughter capacity;
- government should allocate funds to enable farm groups to undertake business planning and obtain expert assistance; and
- government should allocate funds to the Co-operative Development Initiative to enable regional co-ops to provide business expertise to producers.

Federal and provincial financial supports programs were initiated to help the participants of the beef industry after the BSE crisis. Most prominent of them all were the Canada Alberta BSE Recovery Program (CABSERP) and the Canadian Agricultural Income Stabilization (CAIS) program. The Report of the Auditor general of Alberta (pp 53) showed that as at June 2004 Alberta had nine financial aid programs totalling about $402,888,627. The three major Alberta-based packers received directly, in total, at least $45 million out of the $297 million program cost, in payment under CABSERP. These packers (Cargill Foods, Lakeside Packers, and XL Foods Inc.) who control about 90% of the Alberta slaughter capacity also saw a substantial increase in their profits after May 2003, of about $130 per slaughter head, which resulted to a 281% increase in profit margin. This scenario was the product of a distorted market where there is over capacity in cattle supply relative to slaughter levels that declined precipitously.

Assistance either in terms of subsidy or direct cash disbursement of that magnitude in an attempt to avoid harsh economic adjustment could strategically affect the way market participants compete and the entire market structure. Gardner (1975) reported that supporting prices of farm products above the unrestricted market equilibrium level in a perfectly competitive market reduces the price spreads. By implication, any deviation from this finding means the market is non-competitive.

2.3 Effect of Trade Barriers, Increased Cost and Subsidies on the Market Structure

From the discussions in the previous section, external influences as seen in trade restrictions, increased cost of marketing and financial intervention programs especially post-BSE have redefined the market structure in the beef industry. This study represent graphically and algebraically the effect of these forces on a perfectly competitive and non-competitive market structure within the assumption of free trade and no-free trade using a three panel diagram (Houck, 1986), and the effect of border closure to beef and cattle trade between the U.S. and Canada[11]. The Cranfield and Goddard (1999) framework of a multimarket, partial equilibrium of Canadian and U. S. beef and live cattle markets is used.

Before presenting the schematic framework, it will be appropriate to present schematics of the Canadian beef and cattle trade from the cow-calf, to when the beef is exported or sold to consumers at retail stores. This will enhance the understanding of the marketing chain and channel of this commodity.

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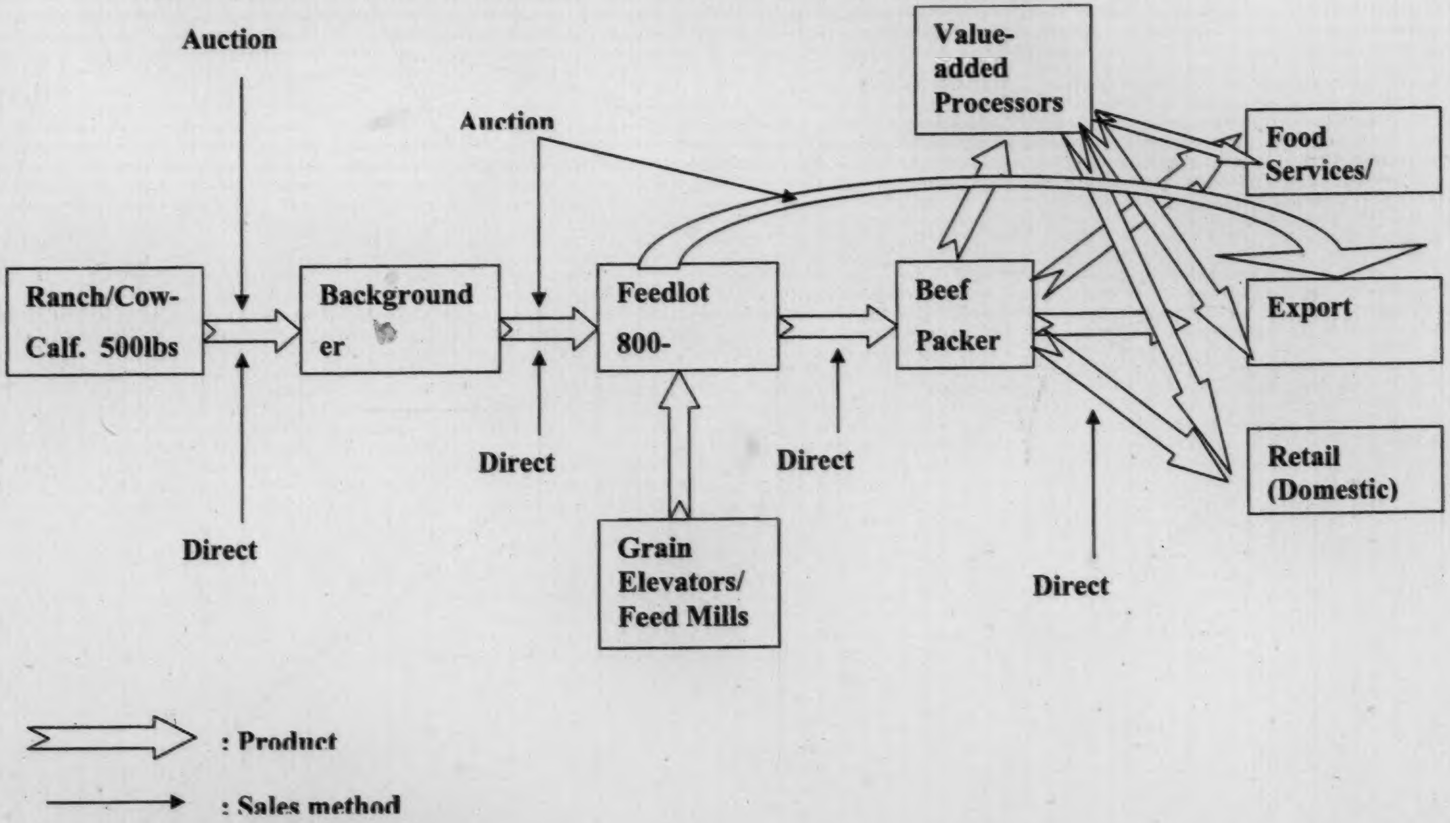
[11] The U.S. is the largest Canadian trade partner in cattle, beef and beef products as such we assume this to be the North American Beef/Cattle trade, with the exemption of Mexico.

Figure 2.1. North American Cattle and Beef Industry Marketing and Value Chain



Source: Grier, K. (2005) (modified).

Figure 2.2 Schematic of a perfectly competitive economic framework.

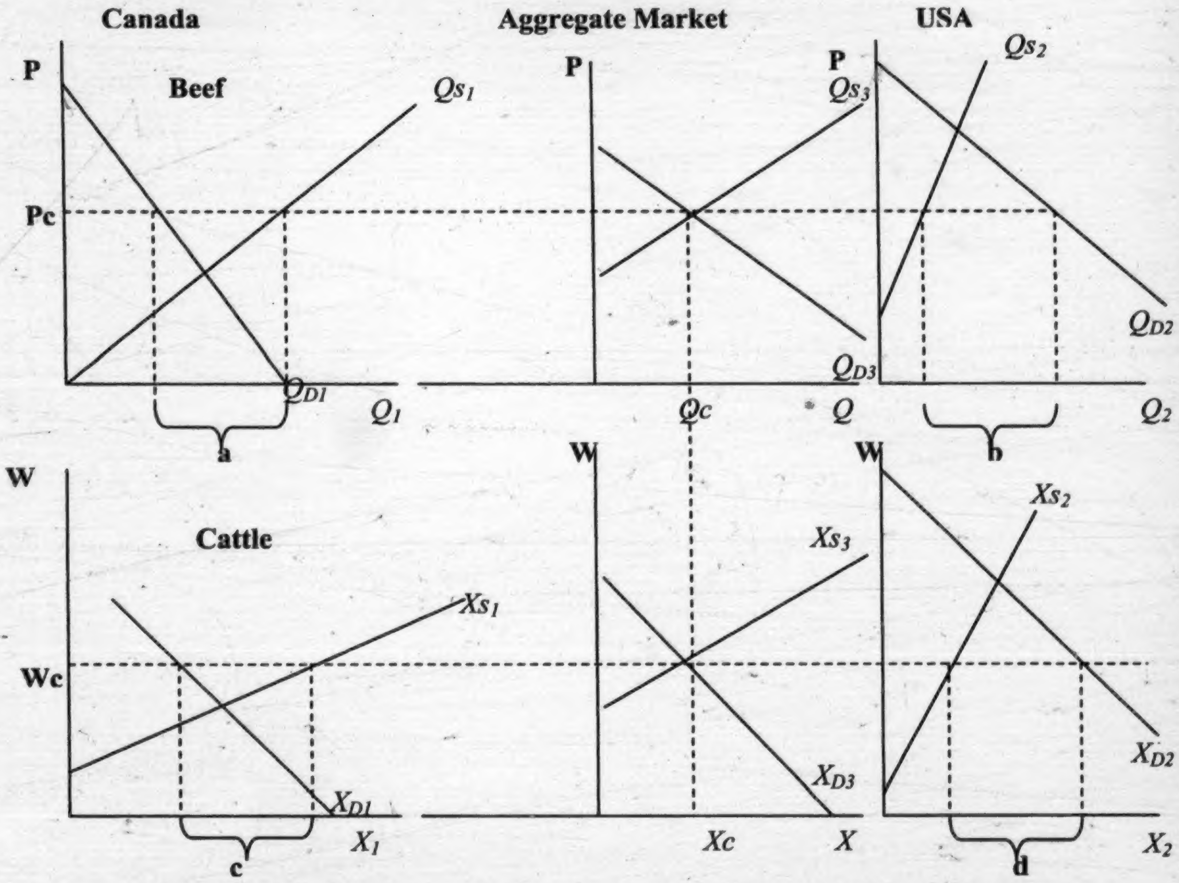


Figure 2.2 is a simplified stylized representation of the equilibrium solution from trade in a perfectly competitive market. Under this situation, we are assuming no exchange rate, transportation costs or trade barrier effects; and Canada is a major exporter while the US is an importing country. Canada and the US trade in the same vertically integrated North America beef/cattle industry. Equilibrium prices, marginal cost and quantities are determined in the aggregate market and are transmitted to the regional markets. Appelbaum (1982) conjectural variation (C.V) framework showed that in a perfectly competitive market, price, *P* (W for cattle) equals marginal cost, *MC*. Therefore, the equilibrium quantity of retail (farm) demand and supply for Canada and the U.S. is determined where $P\ (W)=MC$ intersects the retail (farm) demand curves Q_{D1} and Q_{D2} (X_{D1} and X_{D2}), and the retail supply curves, Q_{S1} and Q_{S2} (X_{S1} and X_{S2}), respectively. The value of *Pc* (*Wc*) is the price, at which the quantity of beef (cattle) exported from Canada-

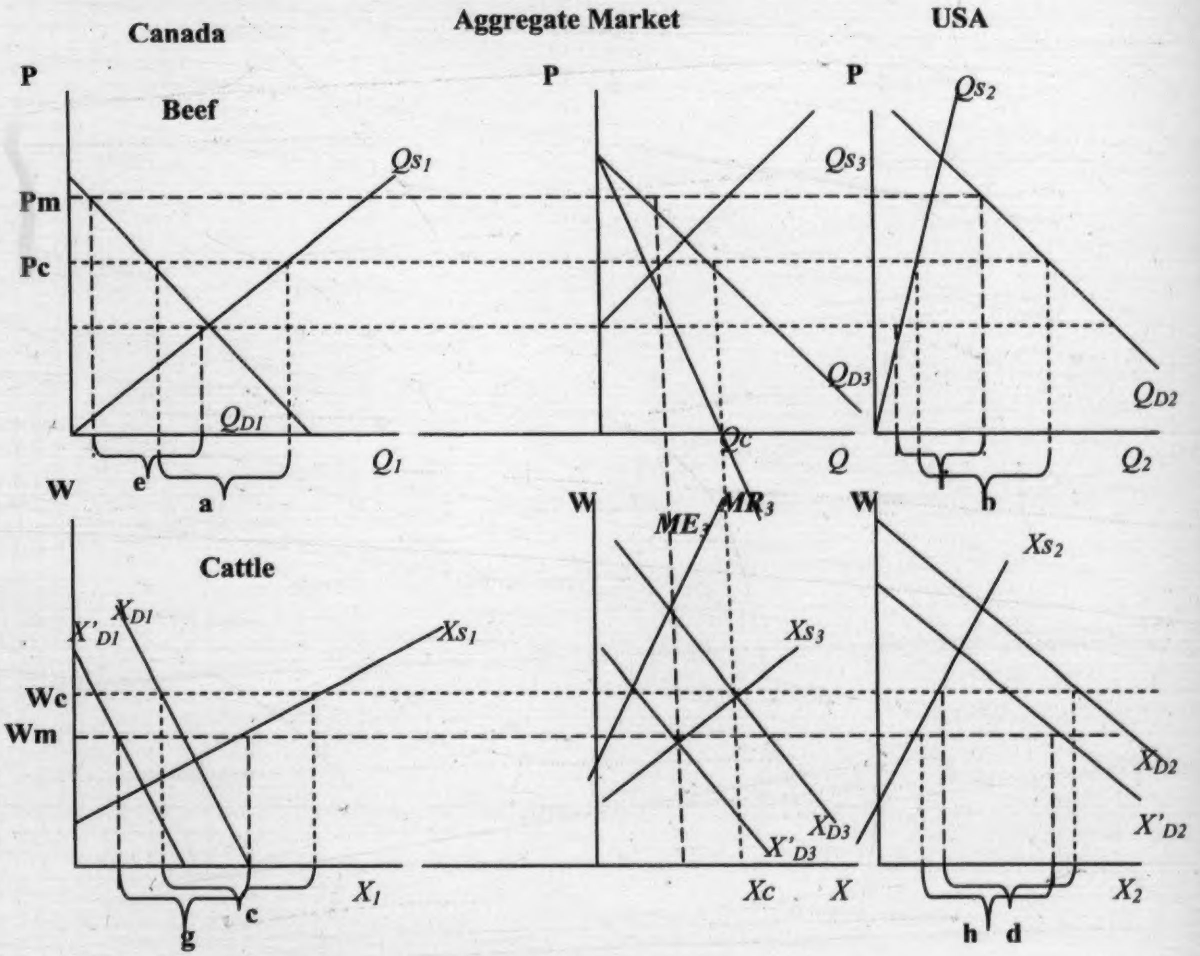
namely, *a (c)* – is exactly equal to the quantity of imports into the U.S.-namely, *b (c)*. It is important to note that the quantity demanded and supplied and their respective prices depends on the slope of the demand and supply curves for both beef and live cattle.

In Figure 2.3, $e = f$ for trade to clear in the beef market under imperfect competition. In the same analogy, equilibrium cattle prices (figure 2.2) are determined in the aggregate market where the derived demand function, X_{D3} or X'_{D3} intersects the farm supply function, X_{S3} or X'_{S3}. The farm prices are then transmitted to the Canadian and U.S. cattle markets where the live cattle supply, X_{S1} and X_{S2}, and demand, X_{D1} or X'_{D1}, and X_{D2} or X'_{D2} are determined respectively. As seen in figure 2.2, the position of the derived demand curve depends on the structure of the output (beef) market. For a perfectly competitive case, $P=MC$ while for an imperfectly competitive case $P > MC$ (figure 2.3). For trade to clear in the live cattle market, $c = d$ *and* $g=h$. Any shift in the domestic supply and demand functions in Canada or the U.S. will shift the position of the equilibrium price and quantity traded in the aggregate North American market. Again, the magnitude of the differences in quantity demanded and supplied and prices for both beef and cattle depends on the slopes of the demand and supply curves.

When output markets are not competitive, $P > MC$, either monopoly or oligopoly market structure manifest (Appelbaum, 1982; Schroeter, 1988). Therefore the derived demand curves associated with imperfect competition (X'_{D1}, X'_{D2} *and* X'_{D3}) lie below those of competitive markets (X_{D1}, X_{D2} *and* X_{D3}) (figure 2.3). When the beef market becomes monopolistic, the marginal revenue curve, MR_3, becomes the aggregate market demand curve and the live cattle marginal outlay or expenditure, ME_3, becomes the supply curve. In this situation beef prices increase over and above perfectly competitive prices and marginal cost, while live cattle prices fall under and below the prices obtained under perfect competition to present a case of monopsony.

For an oligopoly case, the price will be situated somewhere between the monopoly price, P*m*, and the competitive price, *Pc*. This is because in an oligopoly, the perceived marginal revenue curve lies between the demand function, Q_{D3}, and the marginal revenue curve, MR_3 (Cranfield and Goddard 1999) while in an oligopsony, the perceived marginal expenditure cure, lies between the supply function X_{S3}, and marginal expenditure curve, ME_3.

Figure 2.3 Schematics of an imperfectly competitive economic framework



The demand and supply of beef and cattle under perfect and imperfect competition can be represented algebraically as follows:

$$D_b = f(P_b) \tag{2.1a}$$

$$S_b = f(\alpha, D_C) \Leftrightarrow S_b = \alpha(f(P_b, P_C)) \tag{2.1b}$$

$$D_C = f(P_b, P_C) \tag{2.1c}$$

$$S_C = f(P_C) \tag{2.1d}$$

where, D_b, D_C, S_b, S_C are the demand for beef and cattle, and the supply for beef and cattle respectively. P_b, P_C, α are the prices for beef and cattle, and technology coefficients, respectively. However under imperfect competition as seen in figure 2.3, the demand for cattle becomes a function of marginal revenue (MR) and marginal expenditure (ME) or outlay as thus:

$$D_C = f(MR, ME) \tag{2.2}$$

It is then obvious that any influence from trade barriers, increased costs or external intervention in the market will disrupt the competitive equilibrium of the market in figure 2.2. For any trade restriction as the one Canada faced during the BSE crisis, the resultant will be excess capacity of supply of beef and cattle or either one of those. From classical demand and supply theories, excess supply relative to demand leads to declining prices to the point where equilibrium quantity is attained. The relationship in figures 2.2 and 2.3 and algebra above shows that an excess supply of beef affects both retail and farm prices since retail demand determines farm supply; however, excess capacity in only farm supply, assuming no restriction on beef trade, affects only farm prices.

The following figures 2.4 and 2.5 try to show a case of trade with border closure between the two countries and how it affects the major players in the market. One obvious thing is that for cattle production, while cattle producers in the U.S. are better off and happy, their counterparts in Canada are having it rough and tough. Consequently, processors in the United States would have to deal with a small supply of cattle domestically at higher domestic prices, or perhaps from Mexico, while packers in Canada would have to hire more labour to keep with excess domestic supply of cattle at a cheaper price compared to what would have been obtained with open border.

In terms of beef trade, more beef is exported from Canadian packing plants into the United States due to excess supply of cattle in Canada. In this scenario, packers in Canada experience low beef prices due to excess supply of cattle from Canada. However, this might not be the case considering the concentration and multiple ownership of this packing plant across Canada and the U.S. In the case of an unchanging consumer demand, all that is happening is the transfer of excess beef into the U.S. to meet the demand that would have been met with less beef and more cattle import from Canada. Therefore, it is expected that trade effect will balance out and prices in both countries will remain as they were since same firms operates across both borders.

As seen in figure 2.4, producer loss is imminent in Canada and a surplus in the U.S. Producers in Canada receive domestic price of Pb below the competitive price due to close border, which has consequently reduced cattle supply. Meanwhile producers in the U.S. receive higher prices of Pa since production and supply is maintained at domestic level. Figure 2.5 ostensibly show a case of increase consumer surplus, and processor losses in both countries. Excess beef supply and export from Canada would bring down domestic prices, increase international trade supply, and reduce U.S. prices.

Figure 2.4 Trade in Cattle with Border Closed to Cattle Over Thirty Months.

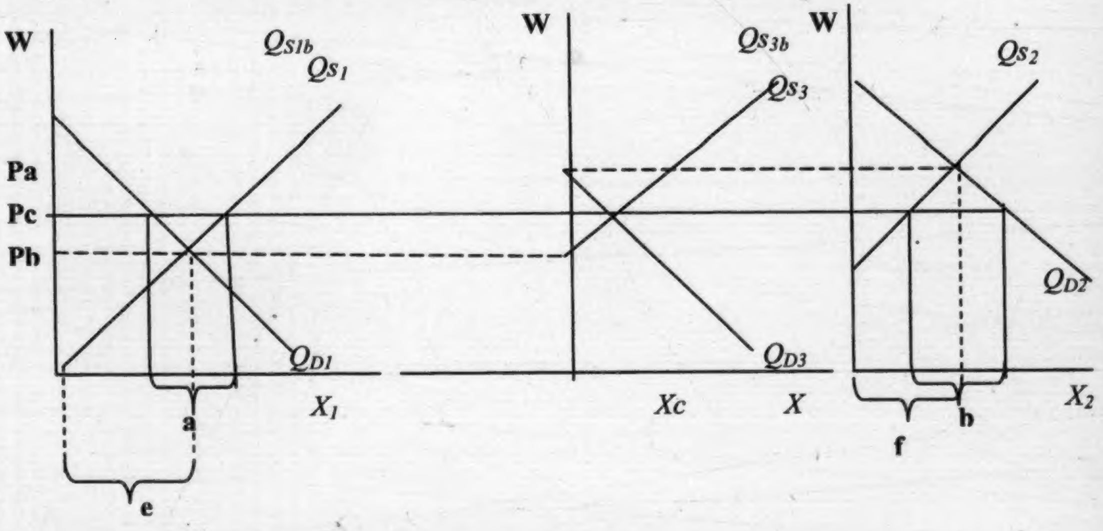
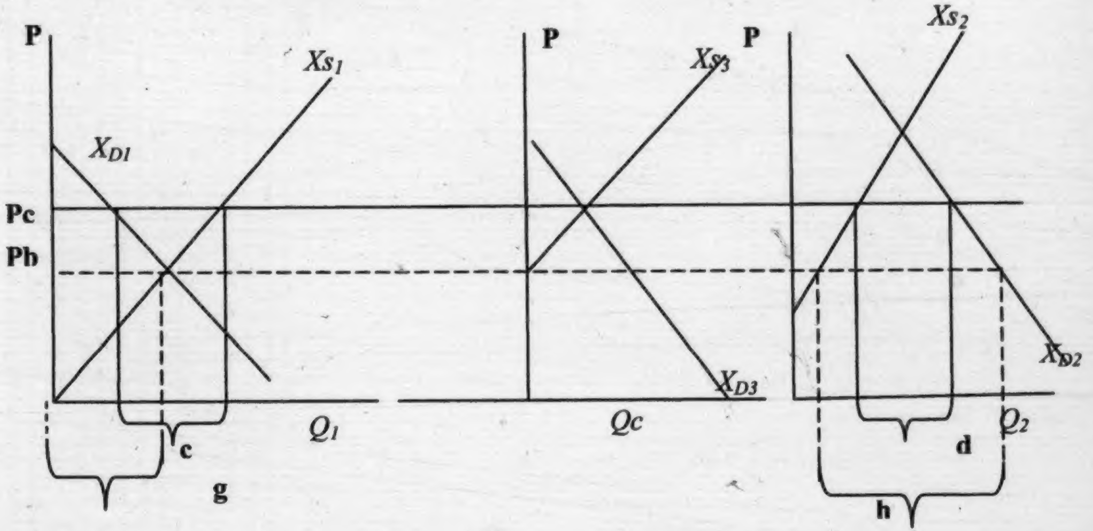


Figure 2.5 Trade in Beef with Border Closed to Cattle Over Thirty Months



2.4 Review of Market Structure/Power Empirical Model

With the exposition of market structure, how it determines pricing systems and how it is been affected by economic shocks such as the ones during the BSE crisis; it is imperative that we look at some of the models that have been and could be used, or built upon to empirically achieve the objectives of this study.

Griffith (2000) highlighted the importance of conducting research into non-competitive behavior in the food chain when he reviewed previous work on market power in the food marketing chain of Australia. Focusing on the results, he found out that such behavior reduced Australian consumer surplus by an estimated A$1 billion and produced a deadweight loss to the economy amounting to A$20 million per year. As a result of these concerns of inefficiencies emanating from non-competitive behaviours of firms, different studies and models have been developed in an attempt to refine the analytical measurement of market structure and market power. This section therefore reviews the empirical models used in studying market structure/power and their applicability to the current study.

2.4.1 Marketing Margin Model (Farm-Retail Price Spread)

The concept of marketing margin assumes simultaneous equilibrium at two market levels with the interaction of supply and demand at the retail level determining the retail price. The demand at the farm gate (producer) level is derived from the retail demand and primary supply. Marketing margin (M) is the difference between the retail price (RP) and producer price (PP) per equivalent unit at equilibrium, and represents the price of marketing services such as processing, storage, wholesaling and retailing (Sanjuan et al 2003). Elitzak (1996) in Wohlgenant (2001) defines the marketing margin as the difference between the farm value and retail price. It represents all assembling, processing, transporting, and retailing charges added to a farm product. Wohlgenant (2001) noted that "specifically, the margin is calculated by subtracting the net farm value equivalent of food sold at the retail of the farm product (farm value less the value of any by-product) from the retail price". The marketing margin can be measured in many different ways (Gardner 1975), for example, as the difference between the retail and farm value of the commodity, by the ratio of retail to farm price, by the farmer's share of the retail dollar, or by the percentage of the marketing margin of retail or farm price.

While price-cost margins are best viewed as net margins because they are net of labour and other variable costs of marketing, the price spread is the difference in the aggregate prices between two marketing levels in an industry per equivalent unit at equilibrium, and represents the price of marketing services such as processing, storage, wholesaling and retailing (Scott, 1983).

Prior to Gardner's (1975) findings that no simple mark-up pricing rule can accurately model the relationship between retail price (RP) and producer price (PP), George and King (1971) had modeled margins, under the assumption that margin behaviour depends on the pricing practices of market middlemen, as a combination of an absolute spread (μ) and a constant percentage of producer prices (k). They hypothesize that margin behavior depends on pricing practices in the upstream sector,

$$M = \mu + kPP \text{ and } RP = \mu + \beta PP \tag{2.3}$$

where $\beta = 1 + k$, β *and* k are coefficients and M is margin. Sanjuan *et al* (2003) however extended this model by allowing different constants when a shock occurs in the system so that $RP = \mu_1 + \mu_2 + \beta PP$ where μ_1 and μ_2 are the constants prior to a shock and after, respectively.

Some of the notable literature addressing marketing margins, their objectives, methodology, data and results they obtained are presented in the table below:

Table 2.3. Previous studies of market power using marketing margin framework

Author/Year/Study	*Objective(s)*	*Research Methods/Data used*	*Findings*
George and King (1971): Consumer Demand for Food in the united states with implication for 1980	*To analyze the demand for food commodities in the postwar United States using both time-series and cross-sectional data*	*A demand interrelationship matrix was developed for 49 commodities groups at the retail level. Data from the 1955 and 1965 USDA household food consumption surveys was used.*	*Found that significant number of commodities displayed combinations of both constant absolute and constant percentage margins*
Gardner (1975): The Farm-Retail Price Spread in a Competitive Food Industry.	*To examine the consequences of competitive equilibrium in product and factor markets for the relationship between farm and retail food prices.*	*Consumer theory and theory of the firm in an equilibrium market framework, while testing for different shocks in the market.*	*Empirical results show that no simple markup pricing rule. Events that increase the demand for food will reduce the retail-farm price ratio if marketing inputs are more elastic in supply than farm products.*
Schroeter, J. and Azzam, A. (1991): Marketing Margins, Market Power, and Price Uncertainty	*To develop a conceptual and empirical framework for analyzing marketing margins in a noncompetitive food industry facing output price uncertainty*	*The framework stems from the Appelbaum's framework and allowed for the decomposition of observed margins into components reflecting marginal cost of the processing industry, oligopoly/oligopoly price distortions, and an output price risk component. Data on farm/wholesale spreads for pork for the 1972.II to 1988.IV period, built from the National Provisioners weekly average wholesale price quotations on a variety of fresh pork primal sections was used.*	*The farm/wholesale margins for pork were found to be consistent with competitive performance in the 1980s than 15years prior, and that a significant output price risk component persisted throughout the sample and ignoring this component in empirical analysis would have led to an erroneous inference of noncompetitive conduct in the product market.*

Holloway (1991): The Farm-Retail Price Spread in an Imperfectly Competitive Industry	*Provide a conceptual framework for the analysis of imperfect competition; assess the analytical consequences of non-competitive behavior, and determine the empirical significance of such behavior.*	*Conjectural variation elasticity from the New empirical Industrial organization (NEIO) methodology. The data used are annual observations for the period 1955-83 on retail and farm prices, quantities of farm commodities, and an index of the price of marketing inputs.*	*Most signs of coefficients conformed to those predicted by the conceptual model; The conjectural elasticity hypothesis (necessary condition) for market power test showed that the market was perfectly competitive within the period under study, but the second hypothesis (sufficient condition) test restricting input cost to be zero revealed beef, veal and pork market to be imperfectly competitive.*
Wohlgenant, M.K. (2001): Marketing Margins: Empirical Analysis	*Looked at the determinants of retail and farm prices, determinants of marketing margins, and factors affecting marketing margins*	*Used reduced forms models of input demand and output supply with various constraints and assumptions.*	*Marketing margin is Influenced primarily by shifts in retail demand, farm supply, and marketing input prices. Other important factors include-time lags in supply and demand, market power, risk, technical change, quality, and spatial considerations.*

2.4.2 Price Spreads/ Transmission Model

As defined in the previous section by Scott (1983), price spread is the difference between the primary and derived demand curves for a product. There is a broad literature on the issue of the margin between the retail and farm levels and what factors may influence it. The most notable early paper on this issue was by Gardner (1975) which identified a range of factors that would influence the price transmission between the farm and retail sectors. Gardner assumed perfect competition which clearly does not fit with the concerns raised in this study. In an imperfectly competitive market price spreads between farm and retail can also exhibit extraordinary profits to market participants (Holloway 1991).

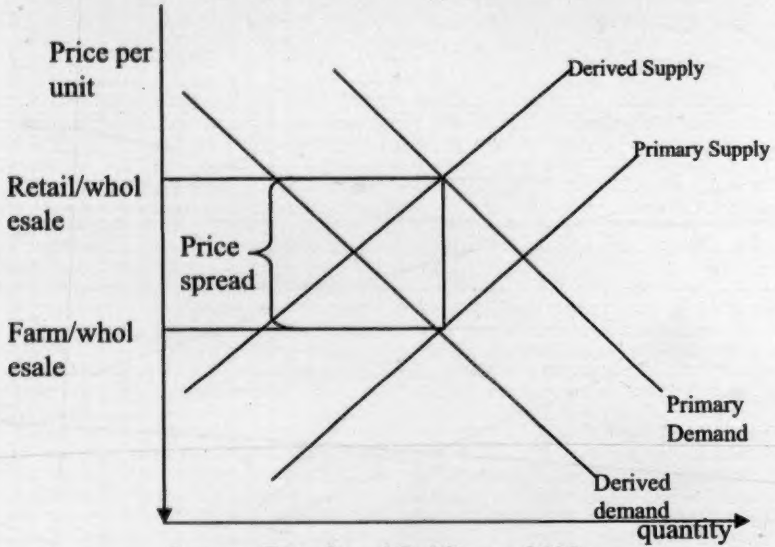
The vertical transmission of shocks among various levels of the market is an important characteristic describing the overall operation of the market (Goodwin and Holt 1999). When changes in farm prices due to shocks are not fully or more than fully transmitted in consumer prices in the short run, asymmetric price transmission becomes the case. McCorriston *et al* (1998) reported that both input substitution and market power cause incomplete price transmission for beef and pork in the U.S. However, Wohlgenant (1989; 2001) and Reed and Clark (1998) couldn't reject the hypothesis that retailers in the U.S. behave competitively in both the demand and supply of a range of products.

To this end, McCorriston *et al* (1998) show that oligopoly power in the food sector would have an impact on determining the price transmission elasticity following a supply side shock depending on the functional form of the demand curve while McCorriston *et al* (2001) show that the extent of returns to scale characterizing the food industry cost function will also be important. Other important influences of the retail-farm margin and hence price transmission are likely to be oligopsony power (Lloyd et al. 2004), and the source of the exogenous shock (i.e. whether the shift occurs in the retail demand or farm supply function (Gardner, 1975). Holloway (1991) extended Gardner's work to involve non-competitive scenario and tests for hypotheses on eight food industries (beef and veal inclusive) market conduct with annual data from 1955-1983. He found no evidence of departure from perfect competition in the output market.

A complete theory of price spread assumes simultaneous equilibrium at two market levels in an industry. The forces of demand and supply at the retail level determines retail prices, and demand at the producer (farm gate) level, which is derived from that at the retail level, and primary supply determines producer prices. The wholesale prices are determined from the retail prices and farm gate prices, other factors held constant. The primary demand is joint demand for all the inputs that go into the final product while the derived demand is the demand schedule for a farm input used to produce a consumer product. Therefore price spreads represents the difference between the two demands. See figure 2.6 for a graphical overview.

It means that price spread behaviour depends upon the slopes of the demand and supply functions relative to each other. Using Gardner's theoretical framework, a perfectly competitive firm uses an agricultural commodity and market services to produce food, and retail food demand is determined by the retail price and an exogenous shifter, say BSE effect. Gardner showed that when the own-price elasticity of demand for a particular food is negative and the supply elasticity of the agricultural commodity is less than that of marketing services, then spread increases if the exogenous demand shifter falls. He also showed that increase in marketing costs increases spreads and any shock to farm supply that reduces producer price as in the case of BSE, increases spreads as well. We accordingly expect that beef price spread will also increase as a result of a change in consumer preferences away from beef following the BSE crisis.

Figure 2.6 Primary and Derived Demand and Supply Under Perfect Competition



Source: Tomek and Robinson, 1990.

Table 2.4 Summary of previous studies on industry structure and market power using price spread framework

Morgan and McCorriston (2005): Market Power and Relative Price Adjustment: Evidence from the UK	*Test for market power using the retail-farm price margin and to outline a procedure that will determine the structure of the co integrating regression if market power is present*	*The Price spread framework of Gardner (1975) using the NEIO and a co integration approach was used. Monthly data is used for 10 commodity sectors in the UK covering 1990-2002. These includes prices of beef and substitutes and BSE meat scare index, and Impact of export ban and the cull in the beef sector*	*Findings suggest that market power in the UK food sector is likely to have played a role in determining price transmission between retail and farm prices. Specifically, market power was found to be responsible for the increasing spread in farm-retail price spread in the beef sector.*
Ben-Kaabia et al *(2005): Asymmetric Price Transmission in the Spanish Lamb Sector*	*To investigate the non-linear adjustment of prices between farm and retail prices in the lamb sector in Spain*	*Cointegration framework based on a three-regime threshold autoregressive model. Weekly time series data on farm and retail prices (Logarithm) were used.*	*In the long run price transmission is perfect and any supply or demand shocks are fully transmitted along the marketing chain. However, in the short run price transmission are asymmetric. Also, retailers benefit from any shock, whether positive or negative, that affects supply or demand conditions.*
Lloyd et al (2004): Price Transmission in Imperfectly Competitive Vertical Markets	*To determine ligopoly/oligopsony retail power in a vertically related market using price transmission.*	*Uses the NEIO CV model and the co-integration framework. Retail and farm prices for beef and substitute meats from the UK's department of Environment, Food and Rural Affairs, and media and meatscare index from 1990-2001*	*Oligopoly is the dominant feature of the UK food retailing sector as such any demand shift is felt more at the farm level prices due to asymmetric transmission.*

Sanjuan & Dawson (2003): Price Transmission, BSE and Structural Breaks in the UK Meat Sector	*To examine price transmission between producer and retail prices for beef, lamb and pork in the UK and the impact of public concern over BSE in early 1996*	*They used the co integration procedure of Johansen et al (2000) that allows for structural breaks in co integrating space. Monthly price data for beef, lamb and pork from the Meat and Livestock Commission for England and Wales for Jan1986-Dec. 2000 is used.*	*Results show that a long-run relationship exists between each producer and retail price with structural break due to BSE affecting price transmission in the beef relationship, which increases the margin by 1.12 pound per kg. No effect was found in the price transmission relationship of lamb and pork*
Frank & Jack (2003): Asymmetric Price transmission in the case of Supply Shocks	*To examine asymmetric price transmission due to market power in the presence of a supply shock*	*An extension of Azzam and Schroeter (1995) CV model comprising of both oligopoly and oligopsony power. Data on farm and retail prices and predetermined demand and supply elasticities from other literatures.*	*Asymmetric price transmission results into market power and in terms of supply shock in cucumber with market power, consumer prices changes more than growers' prices. Input and output substitution is also responsible for asymmetric transmission. Small welfare effect exists with market power but potentially large income distribution effects exist.*
Goodwin & Holt (1999): Price Transmission & Asymmetric Adjustment in the U.S. Beef Sector	*To evaluate price linkages among producer, wholesale, and retail marketing channels in the U.S. beef markets.*	*The threshold co integration error correction model was used. Weekly time series beef prices for producer, wholesale and retail markets was used.*	*Findings suggest that price transmission of shocks appears to be largely unidirectional with information flowing from the farm-wholesale-retail. Farm markets adjust to wholesale shocks but retail*

			shocks are confined within the retail markets. Generally, responsiveness to price shocks have increased over the years
Scott (1983): Analysis of Price Spread Behaviour of Red Meats	*To determine appropriate data source, methodology and to build behavioral equations of estimating price spreads for beef and pork*	*Build spatial/ continental price spread behavioural models following George and king (1971) for red meat in Eastern and Western Canada, and the U.S. Specifically, price spread data was developed from farm, wholesale and retail price data, by-products and costs proxies.*	*The results of her price spread behaviour revealed levelling of the farm to packer price spread and averaging of the packer to retail price spread. Processing costs, by-product values and the dependent price spread lag were found to explain this spread behaviour.*

2.4.3 Conjectural Variation (NEIO) Model

The NEIO models do not rely on accounting definitions of oligopoly power such as profitability rates but rather, they explicitly parameterize industry conduct (Bresnahan 1989). Bresnahan (1989) sees a typical NEIO model first and foremost as an econometric model of how firms in an industry set price and quantity in order to infer the underlying conduct of the industry. Conjectural Variation (CV) model operate on the premise that firms base their output decisions on the response they expect to get from competitors. A limited market response to a change in firm output is indicative of a competitive market, while an elongated response suggests the presence of market power. This framework allows the decision process of a single firm to be affected by the behavior of rival firms. The CV model allows for the direct prediction of a firms' beliefs (conjectures) regarding rivals actions, hence firms behavior assuming the models underlying conditions are accurately described and specified. This model uses empirical data to provide information about the nature of conjectures and is easy to estimate, which makes it a popular choice for measuring and estimating market power (Bresnahan, 1989).

The CV model uses the firm's profit maximization conditions to derive a profit-maximizing output response condition which depends on the price elasticity of cattle supply (input) and beef demand, and on the firms' conjecture about industry response to a change in its own production level or through-put. The conjectural elasticity parameter measures the difference between the cattle input price and the firm's marginal valuation of output called the price-cost margin or Lerner Index (LI)

Despite the fact that they happen to be reduced form models, an empirical literature review revealed that most studies on market power, especially in the beef industry use the Conjectural Variation (C.V.) framework[12]. This approach focuses on market outcomes rather than the underlying competitive process; it relies on reduced form models of competition, which do not require strategic variables, timing of actions, and the information structure faced by firms be fully specified (Fudenberg et al 1987). Firms, in C.V. models are assumed to maximize single period profits (static models), even when it is known to all parties that competition will take place in several future periods (dynamic).

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[12] (Schroeter 1988), (Azzam and Pagoulatos 1990), (Schroeter and Azzam 1991), (Schroeter, Azzam, and Zhang Mingxia 2000), (Wann and Sexton 1992), etc.

Furthermore, in these models, firms are assumed to exercise market power only through their influences on market prices which could be misleading. Azzam (1998), Schroeter (1988) and Azzam and Pagoulatos (1990) found out that a steady supply of inputs to packers is very important, especially when the plants becomes bigger. This shows that strategic variables such as plant capacity utilization are important to packers. Firms present a pseudo-competitive front when they use market power to assure a steady supply of input through their pricing mechanisms.

This concept as presented by Appelbaum (1982) maximizes the profit function of a firm in an industry with N firms producing homogenous product Y.

$$Max\Pi^j = P\cdot Y^j - C^j(Y^j, W_i) \qquad (24a)$$

where P is the output price and Y^j the firm's output quantity, $P\cdot Y^j$ is the revenue function; Y^j is the firm's output and W_i is the firm's input cost while $C^j(Y^j, W_i)$ is the firm's costs function.

Taking the first order derivative of the profit maximization equation yields the CV elasticity and a measure of market conduct and structure.

$$P_x\left(1+\frac{\theta^j}{\eta_{y,p}}\right) = MC \qquad (2.4b)$$

Where $\theta^j = \frac{\partial Y}{\partial Y^j}\cdot\frac{Y^j}{Y}$ is the conjectural variation elasticity for firm j and (2.4c)

$\eta_{YP} = \frac{\partial Y}{\partial P}\cdot\frac{P}{Y}$ is the own price elasticity for the retail product. (2.4d)

MC is the firms marginal cost. In equation (2.4b), the two extremes of θ are easily estimated as perfect competition if $\theta=0$, or monopoly and cartel behavior if $\theta=1$. However, as Holloway (1991) suggested, the close definition of θ gives it an intermediate value as a result of Cournot behavior. Hence, $\theta \in [0,1]$ provides a convenient index of competition within which a broad spectrum of behaviors can be captured. Using symmetry equilibrium, it is important to note the assumptions that firms posses homogenous technology and produce homogenous products hence MC, P_x and η are common to all firms in each region. Therefore $\theta_i = \theta_j = \theta,\ \forall\ i,j \in \{1,2,...,n\}$.

Though Appelbaum (1982) only looked at oligopoly power exertion or markdown pricing by firms, several studies have followed his approach to consider the supply side effect in terms of input (cattle) purchase from the producers by the packers. First by Shroeter (1988) to Azzam and Pagoulatos (1990); Shroeter and Azzam, and Azzam and Shroeter (1991); Stiegert et al (1993); Azzam (1997); Schroeter, Azzam, and Zhang Mingxia (2000) and Anders (2005) have used the CV approach of the NEIO methodology to either singly or simultaneously estimate markdown pricing behaviour in cattle supply in the beef packing industry.

Following Stiegert et al (1993), a generalized Leontief profit function of beef packing is used to estimate markdown pricing for cattle supply by maximizing profit not only as a function of output price and quantity, but also as a function of farm input and quantity. Thus, the industry profit function for beef packing producing output Y is defined as:

$$Max_{y,x_o,X} = py - w_o x_o - WX \quad s.t. y = y(x_o X) \qquad (2.4e)$$

where w_0 is the price of farm input x_o, W is an m-dimensional price vector of non-farm inputs X, and $y(x_o,X)$ is the industry production function, all other variables remaining as previously stated. Demand and supply equations are obtained from the first order condition of the profit function following Hotelling's Lemma. If we keep our assumption of oligopsonistic market structure, then the marginal outlay (MO) by the jth firm will become:

$$w_0^{\bullet} = w_o\left(1 + \frac{\Phi_j}{\varepsilon_j}\right) = MO \qquad (2.4f)$$

where $\Phi j = \left(\frac{\partial x_o}{\partial x_{o,j}}\right)\left(\frac{x_{o,j}}{x_o}\right)$ is the jth firm's conjectural elasticity and $x_{o,j}$ is the jth firm's input employment. Φj is the own price elasticity of supply of cattle. The industry marginal outlay is arrived at by multiplying equation *2.4f* by each farm's share in the farm input market, and summing over the number of firms. The explanation for the conjectural elasticity remains the same as in the oligopoly case.

The CV model generates accurate inferences only in as much as the data used, the demand and supply, and processing costs data are accurate and the functional forms are not mis-specified. Data paucity is another problem why aggregated market level data is used instead of firm-level data to infer firm-level competitive behaviour. Aggregation bias and the inability of empirical functional forms to adequately characterize the in-plant cost structure and demand and supply conditions can significantly reduce the inferential power of the CV approach (Jones 1996). Therefore, accurate estimates of the underlying market and technological conditions are necessary for any conclusions regarding firm conjectures. Below is a summary of studies that have used the C.V approach to model firm and industry behaviour.

Table 2.5 Summary of previous studies on market power using the C.V. framework

Author/Year/Study	*Objective*	*Research Methods/Data used*	*Findings*
Anders (2005): Measuring Market Power in German Food Retailing: Regional Evidence.	*To analyze the simultaneous exertion of retailers' market power in the regional output and input markets of a segment of the German meat market.*	*The NEIO was used based on the production theory proposed by Gohin and Guyomard (2000). Monthly dataset on the regional marketing for beef and pork.*	*Results of findings suggest that the hypothesis of perfect competition and price-taking behaviour clearly has to be rejected. C.V. estimates indicate retailers' upstream and downstream market power in regional meat marketing is limited.*
Lopez et al (2002): Market Power and /or Efficiency: A Structural Approach	*To separate out the oligopoly-power from the cost-efficiency effects of concentration on output prices, and estimate oligopoly power and economies of size in 32 U.S. manufacturing industries.*	*Develops a NEIO model that extends Appelbaum's (1982) model to formally incorporate measures of industrial concentration, analogous to Azzam's (1997) oligopsony model. Data on input and output costs and quantities, and prices are from the National Bureau of Economic Research database on U.S. manufacturing industries.*	*Their results showed that further increase in concentration would significantly increase market power; result in cost efficiency in one-third of the industries; and increase output price in nearly every case. Meat packing showed significant and considerable market power and cost economy trade off effects.*
Morrison Paul (2001): Market and Cost Structure in the U.S. Beef Packing Industry: A Plant-Level Analysis	*To measure cattle input market power and cost (utilization, scale, and scope) economies, with allowance for output market power estimation.*	*A cost function-based production structure of beef packing plants, with profit maximization over cattle purchases and fabricated slaughter, hide and by-products output production. Monthly data on cost and revenue from GIPSA/USDA survey of the forty-three largest U.S. beef pants in 1992-93 was used.*	*The estimates indicate little if any depressing of cattle prices or excess profitability, and significant cost economies in the industry. Larger and more diversified plants have more potential technology economies than smaller plants, and regional variation existing, albeit they require large quantities of cattle input for profitable operation in order to keep capacity utilization at high levels.*

Morrison Paul (1999): Aggregation and the Measurement of technological and market structure: The Case of the U.S. MeatPacking Industry Level Analysis	*To compare evidence from cost function-based evaluation of data at two aggregation levels (aggregated four-digit SIC industry 2011 data and plant level data for for fourty two beef packing plants from USDA and GIPSA) about the technology.*	*A cost function-based production structure of beef packing plants, with profit maximization over cattle purchases and fabricated slaughter, hide and by-products output production. Monthly data on cost and revenue from GIPSA/USDA survey of the forty-three largest U.S. beef pants in 1992-93 was used.*	*Findings from the aggregate data showed that market parameters are significant when only monopoly or monopsony power is accommodated. The plant level data find significant market power parameters only for fabricated output and cattle input. In addition, plants seem to pay slightly more rather than less on the margin than the direct marginal benefit to support unit cost reductions from increased utilization (throughput). Scale economies were also found to exist, which caused evidence of market power to coincide with approximately zero economic profits.*
Bhuyan and Lopez (1997): Oligopoly Power in the Food and Tobacco Industries.	*To estimate and test for the degree of oligopoly power in forty food and tobacco industries, measure the elasticities of scale and test the constant-return-to-scale hypothesis separately for each industry , and to provide estimates of price elasticities of demand at the industry level.*	*The NEIO approach applied using the dual cost function-based estimation. The U.S. four-digit SIC annual data on input, output and costs is used for this study.*	*The results from the Lerner indices, conjectural variation and demand elasticities shows that 37 of these industries exert statistically significant degrees of oligopoly power and that 82% of these industries exhibit non-constant returns to scale.*
Driscoll, (1997): Nonparametric Tests of Profit Maximization in Oligopoly with Application to the Beef Packing Industry.	*To test for static profit maximization given non-competitive behavior and market power in the beef packing industry*	*The NEIO methodology as proposed by Appelbaum with and nonparametric measure used for both input and output markets. Weekly plant-level data between 1992 and 1993 from GIPSA were used. Data on input*	*The nonparametric maximum likelihood estimates indicates very little evidence of oligopolistic or oligopsonistic behavior Also, results suggest that neither beef packing plants nor firms engage in static profit maximization behavior, and these large violations of static profit*

		and output quantities and prices, and costs were collected.	*maximization may indicate that producers follow some other optimization rule.*
Schroeter (1988): Estimating the degree of Market Power in the Beef Packing Industry	*To assess the monopolistic and monopsonistic performance of the U.S. cattle/beef market*	*An extension of Appelbaum's Consumer theory and theory of the firm to estimate conjectural elasticities and lerner indexes. Data are those of inputs and outputs from the U.S. beef packing industry*	*Results reveals small, but statistically significant monopoly/monopsony price distortions in slaughter cattle and wholesale beef but, in spite of heightened concentration, no indication of appreciable less performance of late in the industry was found.*
Appelbaum (1982): The Estimation of the Degree of Oligopoly Power	*To provide a framework within which a non-competitive firm or industry can be empirically studied and to provide a measure of oligopolistic power of an industry that can be used to identify the underlying market structure of an industry.*	*Consumer theory and theory of the firm to estimate conjectural elasticities and lerner indexes. Data for labor capital and intermediate inputs for four U.S. industries gotten from the manufacturing industry classification of the survey of current business.*	*Findings were that the U.S. rubber and textile industries are characterized by competitive behaviour while the electrical machinery and tobacco are characterized by significant oligopolistic behaviour.*
Feinberg (1980): The Lerner Index, Concentration, and the Measurement of Market Power	*Attempt to calculate an improved average Lerner Index (LI), one which more accurately measures the deviation of price from economic cost by examining the degree to which particular structural measures correlate with the LI*	*LI from the NEIO methodology was used and some other econometric regressions. Data from the 1972 census of manufactures on value added, rental, labor and advertisement costs, cost of capital and shipment values.*	*Found that a better measure of exploited market power is the LI less advertising cost and return to capital. Also, "net seller advantage" was found to be correlated across industries with the LI and seems useful as a proxy for the "degree of monopoly power in force".*

2.4.3.1 Summary of Market Structure/Power Models

This section has provided a brief review of the empirical models used in studying non-competitive behaviour from market structure/power and their applicability to the current study. Ranging from marketing margin from the structure-conduct –performance school of thought and conjectural variation models of the NEIO school of thought models, we looked at various literature that addressed this issue.

The concept of marketing margin assumes simultaneous equilibrium at two market levels with the interaction of supply and demand at the retail level determining the retail price, while price spread is the difference between the primary and derived demand curves for a product. The C.V. model on the other hand, uses the firm's profit maximization conditions to derive a profit-maximizing output response condition which depends on the price elasticity of cattle supply (input) and beef demand, and on the firms' conjecture about industry response to a change in its own production level or through-put and its output quantity and prices. These three models basically use the same data with little extensions based on individual needs but are not necessarily the same. They use demand, supply and cost data in determining market structure and measuring the level of firm competition.

2.5 North American Beef Model(s)

Recently many of the oligopoly/oligopsony models in North America have been developed under the framework that considers market participants' decisions within an imperfectly competitive framework as in Martin and Haack (1977); Schroeter (1988); Schroeter and Azzam (1990); Azzam and Pagoulatos (1990) ; Koontz et al,(1993); Cranfield (1995); Driscoll et al, (1997); Bhuyan and Lopez (1997); Muth and Wohlgenant (1999); Morrison (1999; 2000); Schroeter et al, (2000). In all these models there seems to be the dominant use of the conjectural variation approach of Appelbaum (1982) with little extensions and additions of other variables. For example, Cranfield *et al*. (1995) introduces advertising to this framework and fully integrated the U.S. and Canada beef industry econometrically, Schroeter *et al* (2000) introduced a risk component, and Morrison (1999, 2000) emphasized the relevance of cost economies in estimating these models. This section reviews the literature that have applied this approach in the beef industry in North America.

Since most of the studies using the NEIO school of thought have used totally, or to some extent, the conjectural variation elasticity of Appelbaum, it becomes imperative then to review it first. Appelbaum considered a non-competitive industry in which n number of firms produced a homogenous output Q^j using inputs $X_i = (x_1,...,x_n)$ purchased at price W_i. This is under the assumption that individual firm's output decision affects industry prices, firms cannot affect input prices and each firm faces the same market demand curve. Therefore firms input demand functions can be derived from their cost functions by applying Shephard's Lemma[13],

$$x^j = \frac{\partial C^j(w_i,Q^j)}{\partial w_i}, \qquad j = 1,...,n, \tag{2.5}$$

where x^j is the jth firm's input demand vector and $\partial C^j / \partial w_i$ is the column vector of partial derivatives of C^j with respect to w. Hence the jth firm's profit maximization problem is (Appelbaum, 1982):

$$Max_{Q^j}\left[P.Q^j - C^j(w_i,Q^j): P = f(Q,Z); Q = \sum_{i=1}^{n} Q^j\right] \tag{2.6}$$

Where

$P \quad \equiv Output\ price,$

$Q \quad \equiv total\ industry\ output,$

$Q^j \quad \equiv jth\ firms\ output,$

$C^j(.) \quad \equiv jth\ firms'\cos t\ function$

$f(.) \quad \equiv market\ demand\ curve,$

$Z \quad \equiv demand\ shifters,$

$w_i \quad \equiv ith\ inputs'\ price.$

The firm's first order profit maximization optimality condition is:

$$P + \frac{\partial P}{\partial Q^j} \cdot q^j - \frac{\partial C(w_i,Q^j)}{\partial Q^j} = 0 \tag{2.7a}$$

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[13] See Shephard (1970) and Chambers (1997).

In a perfectly competitive market, $\frac{\partial P}{\partial Q^j}=0$ whereas in a non- competitive market as being considered $\frac{\partial P}{\partial Q^j}\neq 0$. Further manipulation of the first order condition given in (2.7) resulted in the following:

$$\frac{\partial Q}{\partial Q}.\frac{Q}{Q}\left(P+\frac{\partial P}{\partial Q^j}.Q^j\right)=\frac{\partial C^j\left(w_i,Q^j\right)}{\partial Q^j} \tag{2.7b}$$

$$P+\frac{\partial P}{\partial Q^j}.Q.\frac{\partial Q}{\partial Q^j}.\frac{Q^j}{Q}=MC^j \tag{2.7c}$$

$$P\left(1+\frac{\theta^j}{\eta_{Y,P}}\right)=MC^j \tag{2.8}$$

where MC^j ≡ the jth firms' marginal cost,
θ^j ≡ jth firms' conjectural variations elasticity, and
$\eta_{Q,P}$ ≡ own price demand elasticity.

The optimality condition as expressed in (2.8) says that the firm equates its marginal cost with its *perceived* marginal revenue (Appelbaum 1982, p.289). Under perfect competition

$\theta^j = 0$ and under pure monopoly $\theta^j = 1$, '...providing us with two benchmarks which can be used to identify the actual underlying market structure,...in other words, the degree of oligopoly power is between zero and one'. (Appelbaum 1982, p.290). The degree of oligopoly/oligopsony power[14] of the industry, which is a weighted sum of the squared shares of the firms in the industry multiplied by the inverse demand elasticity, is therefore defined as:

$$L=\sum_j \theta^j S_j^2\eta\,;\quad L=\frac{\theta^D}{\eta}\quad \text{and}\quad L=\frac{\theta^S}{\eta} \tag{2.9}$$

where S_j^2 is the Herfindahl index.

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[14] See Azzam *et al.*, (1990) for monopoly price distortion and, Schroeter (1988) for relative monopsony price distortion.

For convenience and for unavailability of firm level data, Appelbaum (1982) suggested that the problem be handled at an aggregate level with the assumption that an aggregate cost function exist to treat the optimality conditions on an aggregate industry level. By using the Gorman polar form type cost function

$$C^j(w_i,Q^j)=Q^j.C(w_i)+G^j(w_i) \qquad j=1,\ldots,n. \tag{2.10}$$

where C(w_i) ≡ marginal cost and

G^j(w_i) ≡jth firms' fixed cost.

This satisfies the condition whereby firms have linear and parallel expansion paths, so that each firm faces the same marginal cost. The cost function presented in (2.10) is said be non-negative in input and output quantity, non-decreasing in input prices, concave and homogenous, non- decreasing in output, and allows all the different firms to have different cost curves but the curves are all linear and parallel (Appelbaum1982; Chambers 1991 p.52). This assumption can therefore yield the following constant returns to scale (CRS)[15] technology industry cost function:

$$C=Q.C(w_i)+\sum_{j=1}^{n}G^j(w_i) \tag{2.11}$$

It also means that each firm will have the same conjectural elasticity since each firm faces the same marginal cost in the industry; thus, the equilibrium equation (2.8) now becomes:

$$P\left(1+\frac{\theta}{\eta_{Q,P}}\right)=MC \tag{2.12a}$$

where P ≡ output price,

MC ≡ average industry marginal cost,

Θ ≡ average industry conjectural elasticity.

Equation, (2.12) is further expressed as:

$$\frac{P-MC}{P}=\frac{\theta}{\eta_{Q,P}} \tag{2.12b}$$

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[15] Bhuyan and Lopez (1997) used an analytical framework of Appelbaum based on a dual translog cost function to allow for non-constant returns to scale

The right hand side of (2.12b) is the generalized form of the LI as expressed in equation (2.9).

Cranfield (1995) seems to be the only study that has explicitly integrated the North American beef model by dividing North America into regions using the Appelbaum's framework, and including the effect of both brand and generic advertising as demand shifters. It developed and estimated price linkage equations, and identities relating supply, demand and trade between the U.S. and Canada. Other literature have normally been country-specific in their econometric model specifications.

Cranfield (1995) added to this maximization problem advertising as a shifter and contended that advertising affects oligopoly power through the demand elasticity by shifting demand or changing quantity demanded; and through the market structure. These two effects respectively affect the Lerner Index and the Conjectural elasticity. His modified profit maximization decision for a jth firm that advertises in a kth region looks like this:

$$MAX_{Q^{k,j}}\left[\begin{array}{l} P.Q^{k,j}-C^{k,j}\left(w_i^k,Q^{k,j}\right)-ADV^{k,j}:P=f(Q,Z,ADV); \\ Q=\sum_k\sum_j Q^{k,j};ADV=\sum_k\sum_j ADV^{k,j} \end{array}\right]$$

where $ADV^{k,j}$ is advertising expenditure for for the jth firm in the kth region and all other arguments remain as previously defined. He specified regional[16] demand equations; regional cost functions of the Gorman Polar type, which summed up into a North American cost function; and a price linkage equation linking the U.S. price to that of Canada to account for exchange rates. Regional and North American beef processors' conditional cattle demand equations, which originated from the first order condition of the cost functions was developed too; and finally these equations were used to measure the North American oligopoly power from the first order condition of the processors' profit maximization equation. Cranfield (1995) also went ahead to build a complete supply response model consisting of regional cattle inventory, price linkage, carcass weight and cattle slaughter equations.

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[16] The regions consist of Western and Eastern Canada, and the U.S.

Schroeter (1988) extended the theoretical framework of Appelbaum's technique and adapted it to the assessment of monopolistic and monopsonistic performance in the U.S. beef packing industry. This enabled him to test for the competitiveness of the industry's input and output markets. This particular technique was used by Azzam and Pagoulatos (1990); Schroeter and Azzam (1991); Azzam (1997); Schroeter et al (2000); Lopez et al (2002); Anders (2005); e.t.c. In Shroeter (1988), the problem of the jth firm is to choose a material input/output, Q^j, assuming a fixed proportion technology, to maximize the profit function:

$$pQ^j - w_M Q^j - C^j\left(Q^j, w\right)$$

Subject to some predetermined demand and supply functions, and a first order necessary condition

$$p\left(1+\theta^j/\eta\right) = w_M\left(1+\theta^j/\varepsilon\right) + \partial C^j/\partial Q^j \qquad (2.13)$$

where $\eta = \left(\partial Q/\partial p\right)p/Q$ is the elasticity of market demand;

$\varepsilon = \left(\partial Q/\partial w_M\right)w_M/Q,$ is the elasticity of material input supply; and

$\theta^j = \left(\partial Q/\partial Q^j\right)Q^j/Q,$ is the jth firm's conjectural elasticity.

His proposed measure of monopoly/monopsony power in terms of price distortion directly is the Lerner index and another index developed, which denotes the difference between marginal net revenue product and factor price as a proportion of factor price.

$L^j = -\theta^j/\eta$ and

$M^j = \theta^j/\varepsilon$

Finally, applying Shepherd Lemma to the Gorman polar form generalized Leontief cost function produced the material and non-material inputs demand functions for estimations. Azzam and Pagoulatos (1990) applied the same technique but instead, used a logarithmic translog production function to allow for a more variable proportion technology for the non-material inputs.

In Azzam (1997), the market power effect of concentration was separated from its cost-efficiency effect, and the effect of concentration on output and input prices estimated. This is replicated in Lopez et al (2002)[17] and Anders (2005), except the fact that while the first two studies were done on US beef packing industry and 32 food processing industries respectively, the latter analyzed the German retail industry.

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[17] Lopez et al (2002) estimated only oligopoly power and cost economies

They show that the cost function is of the modified generalized Leontief form

$$C_j(q,W) = q_j \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + q_j t \sum_i \gamma_i w_i + q_j^{2} \sum_i \beta_i w_i,$$

The FOC of the industry profit function yields, respectively, the industry-wide analogue of the supply relation

$$p = -\frac{H(1+\theta)}{\eta} + \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + t \sum_i \gamma_i w_i + 2HQ \sum_i \beta_i w_i,$$

and factor demand

$$\frac{X_r}{Q} = \sum_i \sum_j \alpha_{ij} \left(\frac{w_j}{w_i} \right)^{1/2} + t\gamma_i + HQ\beta_i \quad \text{for } r = 1, 2, \ldots, k,$$

where $H = \sum_j s_j^2$ is the Herfindahl index, θ is the industry (weighted) conjectural variation and $Xr = \sum_j x_{rj}$ is total industry employment of the *r*th factor.

The first term on the right-hand side of the supply relation is the mark-up over marginal cost. Its magnitude depends on the level of concentration (*H*), the semi-elasticity of demand (η), and the type of market conduct (θ). If conduct is competitive, then $\theta = -1$ and the markup is zero. For Cournot, $\theta = 0$ and the markup is $-H/\eta$. For conduct that is less competitive than Cournot, $0 < \theta \leq (1/H) - 1$ and the upper bound on the markup is $-1/\eta$. However, for noncompetitive conduct, concentration affects both the mark-up and marginal cost.

Azzam (1997) treated θ as a constant. Thus, differentiating the supply relation with respect to *H* yields the decomposed effects of concentration on output price:

$$\frac{dp}{dH} = -\frac{(1+\theta)}{\eta} + 2Q \sum_i \beta_i w_i,$$

where the first term on the right-hand side is the oligopoly-power effect and the second is the cost-efficiency effect (or the effect of a rise in concentration on marginal cost). A measure for the cost elasticity with respect to output is given by the ratio of industry marginal cost to average cost

$$e_{cy} = \frac{A + 2HQB}{A + HQB}, \qquad (2.14)$$

where $A = \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2} + t \sum_i \gamma_i w_i$ and $B = \sum_i \beta_i w_i$,

Where e_{cy} depicts economies of size and is the inverse of the degree of returns to scale. If $B = 0$, constant returns exist, and the only effect of rising concentration on price is through oligopoly power. If $B > 0$, diseconomies of scale exist, and a rise in concentration raises prices through a rise in both oligopoly power and costs. When economies of scale are present $(B < 0)$, the effect of a rise in concentration on price can be positive, negative, or zero, depending on whether the oligopoly-power effect is larger than, smaller than, or the same as the cost-efficiency effect.

Anders (2005) considered both input and output sides of the market following the procedure of Gohin *et al* (2000) and Azzam (1997) while assuming a profit-maximizing retail industry. The problem is to choose optimal quantities of Qi which maximize the aggregate industry profits taking into account their economic environment. He aggregated the profit function of the retail/processing industry considering the distribution of i meat products to be:

$$\Pi_i = \sum_{i=1}^{n} p_i.Q_i - \sum_{i=1}^{n} w_i.Q_i - C_i(Q_i, z) - CF\ .$$

where p_i is the consumer price of beef and w_i the price of the meat input at the retailers'/wholesalers' market levels. Ci is the total cost function of the industry and CF a fixed cost term. The study assumed that the meat products i are demand-related but naturally not supply-related. Taking the first order condition of the maximization problem and applying additional algebra led to:

$$p_i = w_i + H_i(z) - \sum_{i=1} \sum_{i=1} \eta_i.\theta_i.p_i.\left(\frac{Q}{Q_i}\right) + \sum_{i=1} \sum_{i=1} \varepsilon_i.\theta_{ii}.w_i.\left(\frac{Q}{Q_i}\right) \qquad (2.28)$$

where $\varepsilon_i = (\partial Q_i/\partial w_i)*(w_i/Q_i)$ is the elasticity of supply measured at the meat processors/producers market level and $\eta i = (\partial Q_i/\partial p_i)*(p_i/Q_i)$ is the price elasticity of final demand at the retail/wholesale level. $\theta_i = \theta_{ii} = \Sigma(\partial Q/\partial q_i)*(q_i/Q_i)$ are average elasticities of conjectural variation with respect to the final good output (θ_i) and the wholesale/producer factor input (θ_{ii}) as downstream consumers/retailers and upstream meat processors/producers.

2.6 Summary

In this chapter the effects of BSE crisis in terms of increased cost, trade barriers and government assisted programs is looked into. Situations of free competitive trade and non-competitive trade are graphically analyzed, and an analysis of trade barrier in the form of border closure in the Canadian-U.S. BSE crisis is performed. Farmers loss in terms of cattle trade in Canada and gain in the U.S., while processors are supposed to loss in both countries in terms of excess beef supply from Canada into the United States accompanied by a gain in consumer surplus. A review of market power models is also presented with much emphasis on the conceptual framework of the C.V. model. Different North American oligopoly and oligopsony models are also reviewed.

The Canadian and North American beef cattle market structure, beef retailers and processors Oligopoly and oligopsony power is simultaneously accounted for in the conjectural elasticity model, while cost economies effect is captured through a derivation that compares both marginal and average costs as used by Lopez et al (2002). The regional model and parameters as used by Cranfield (1995) in creating the spatial classification of regions was looked at. Past research is also reviewed with respect to the type of market power model, objectives, data used and general results. The next chapter will therefore consist of the development of a conceptual model that will basically consider consumers' retail demand and supply response process for cattle upon which the empirical estimation will be based.

Chapter Three: CONCEPTUAL MODEL STRUCTURE

3.1 Background

In the previous chapter, a review of literature on BSE and the effect of different economic and government interventions on the cattle and beef industry was done. A review of the market power models with particular emphasis on the C.V. model, and the North American beef models was also presented. The aim of this chapter is to develop a conceptual framework in achieving the objectives of this study.

This chapter will therefore consider the scope of this thesis investigation in terms of markets considered and time periods, analytical techniques and estimation methods; a review of the modelling components; a schematic overview of the modelling process and derivation of market closing identities for the model.

3.2 Scope of the Investigation

This section is set to define the scope of the analysis in terms of the modeling technique, and markets to be considered endogenous to this analysis. Measuring of the impact of cost in terms of analyzing market power and structure, while taking into account the BSE and other trade distortions requires appropriate techniques. In this study several market competition models are identified and most suitable approach is selected to be used in the analysis.

Therefore the model selection criteria will include data availability, time restrictions, implementation, underlying assumptions and ability to test axioms and hypotheses. The market competition models reviewed are also going to be considered under the premise of whether they are partial or general equilibrium models.

3.2.1 Analytical technique

On the one hand, partial equilibrium models consider one market in isolation from all other ones, which seems unrealistic because economic systems link markets through price relationships. Though easy to specify and estimate, the partial equilibrium models have a tendency to produce limiting and too-constrained results especially in the marketing of beef vis-à-vis other meat types that stand as substitutes and complements.

The general equilibrium models on the other hand consider all goods in an economy in relation to one another, which exposes it to being tedious and cumbersome to estimate especially when the good of interest is only a small part of the economy. One major merit of the general equilibrium model is it helps identify multi-market inter-relationships, which requires the identification of relevant market and their linkages through price, trade and technical relationships (Cranfield, 1995). The general equilibrium model estimates demand and supply in each market, which gives room for the evaluation of policy shocks on market participants in terms of loses and gains.

Within the multi-market approach, there are two types of demand relationships that exist-the inter-related multi-equation demand system from an underlying utility or expenditure function and the ad hoc single equation, which allows the researcher to include factors they think influences demand. Though the former presents a robust result in terms of allowing for thorough testing of underlying demand theory assumptions and relationship between goods, the later approach seems easier to estimate and better suited for policy analysis. Thus, the ad hoc single equation demand will be used in the analysis.

On the supply side of cattle production, the supply of fed cattle is modeled using the most common model of supply response - Nerlovian model, which specifies output as a dynamic function of the expected price, output adjustment and some other exogenous variables. The price variable is deflated and price expectations are captured via a distributed lag specification. The presence of lagged output variable in an estimated equation is known to result in a high explanatory power of the model; it might also reduce or eliminate autocorrelation (Nerlove and Fornari, 1998). Quarterly disaggregated data helps capture the changing dynamics of the industry in terms of the impact of fed cattle markets on the fed and non-fed cattle markets. The feed-grain market is not considered in the bigger model due to the complexity of modeling the presence of regulatory bodies such as the Canadian Wheat Board and given the fact that Canada is a small player in the world grain market. Therefore it is assumed that Canada is a price taker in terms of grains.

This study will therefore use an econometric multi-market model that will include beef demand, cattle production or supply and beef processor behaviour to estimate parameters necessary for achieving its objectives. The econometric approach (conjectural variation) as against the optimization and simulation approaches was chosen since it allows for explicit testing of hypothesis, and measurement of some currently unknown relationships, and the estimated model simulated using identities for policy analysis.

3.2.2 Estimation method

Demand and supply specifications as functions of price increase the tendency for simultaneity, especially when an endogenous variable is used as an explanatory variable in another equation. This makes the endogenous explanatory variables have a non-zero correlation with the error term as such violating the assumption of the Best Linear Unbiased Estimator (BLUE) model (Judge et al., 1985). Sine these equations are prone to simultaneity, we try to correct for unbiased estimates by either using reduced form equations and try to identify structural parameters from the reduced form parameters, or use various simultaneous equation estimators to estimate the structural parameters. Using the reduced form equations gets eluded of structural parameters, which are necessary for policy evaluation.

Since we cannot rule out the presence of correlation between error terms in the structural equations, then the use of estimators such as the Two Stage Least squares (2SLS) , Limited Information Maximum Likelihood (LIML) function, Three Stage Least Squares (3SLS) and the Full Information Likelihood function (FIML) becomes important since such structural equations require systematic estimation. However, these estimators have a high computational cost and data requirement and the degree of bias reduction as a result of simultaneity is questionable. Therefore, for ease and practicality where necessary, and with some assurance of reduction in bias, the Ordinary Least Squares (OLS) estimator is better after correcting for correlation between explanatory variables and residuals. This study will therefore use the non-linear least squares (LSQ), FIML and OLS as the need suffices.

3.2.3 Periodicity and markets considered

Within the North American cattle beef markets, Canada and U.S trade in both cattle and beef while Canada trade in live cattle with both the U.S. and Mexico. However, Canada imports and exports beef to other countries also such as Australia, New Zealand, Brazil, e.t.c., apart from the U.S. The extent of beef and cattle trade between the United States and Canada is so huge so much that in 2005, 89 % of beef exports went to the U.S. with only 9 % to Mexico (Canfax Statistical Briefer, Oct. 2006). Furthermore, evidence from the data used in this study show that in the Canadian market, off-shore beef exports outside the U.S. traditionally accounted for about 13 % of total beef disappearance. This consideration makes off-shore trade exogenous to the model. Mexico being such a small player in the North American market and due to data availability and time will not be endogenous in the North American market. Therefore, the U.S. beef and cattle trade with Canada becomes endogenous in the modeling.

In an attempt to capture variability and differences in production patterns and for ease of estimations while following other research (Cranfield and Goddard, 1999; Martin and Haack, 1977), this study categorized the North American cattle and beef market into regions as follows: Western Canada, Eastern Canada and the U.S. Quarterly data is used for this analysis so as to reflect the dynamics of modeling and thus improve empirical estimations.

Since one of the purposes of this investigation is to capture the effect of BSE in relation to its effect on the Canadian and North American cattle beef industry, per capita beef demand is estimations in two different periods: Pre and the entire sample that includes post BSE.

3.3 Modelling Components

Conceptually, this section tries to look at the theories and restrictions behind retail meat demand by consumers and producers supply response of live cattle, and beef processors profit maximizing behaviours. It also includes the review of past empirical specifications of these models and the specification used for this study. Some of these analyses are done pre and post BSE so that the effect of the BSE shock can be calculated using some stated assumptions.

3.3.1 Consumer Theory and Demand

Neoclassical consumer theory involves decisions that influence consumers' utility function hence, consumption behaviour based on available resources or budget constraints. It is predicated on a series of axioms and assumptions of rational behaviour by consumers. These axioms are those of reflexivity, completeness, transitivity, continuity, non-satiation and convexity (Deaton and Muelbauer, 1980).

Based on the concept of rationality, a consumer tries to achieve the maximum satisfaction from consuming a good within a given budget constraint. Therefore, the consumer choice problem of maximizing an objective function subject to a budget constraint is given by:

$$MAX_{Qi}\, U(Q_i, y/\beta)$$

$$\text{Subject to : } \sum_{i=1}^{n} P_i . Q_i \leq M$$

Where:

$U(\bullet) \equiv$ *a well defined utility function,*
$Q_i \equiv$ *consumption of the ith good,*
$y \equiv$ *consumers' income,*
$P_i \equiv$ *price of ith good,*
$\beta \equiv$ *parameters of the utility function.*

The decomposition of the above equation, with Qi greater than or equal to zero, into a Langrangian function using the Langrangian multiplier will result into the following:

$$MAX_{Qi,\lambda}\ \ell = U(Q_i, y/\beta) + \lambda\left(M - \sum_{i=1}^{n} P_i \bullet Q_i\right) \qquad (3.1)$$

The first order condition of consumers' utility maximization is then obtained by differentiating the Langrangisn multiplier with respect to all the goods and λ. Thus:

$$\frac{\partial \ell}{\partial Q_i} = \frac{\partial U(Q_i, y/\beta)}{\partial Q_i} - \lambda . P_i = 0 \qquad \forall_i$$

$$\frac{\partial \ell}{\partial Q_i} = M - \sum_{i=1}^{n} P_i . Q_i = 0$$

If we assume the presence of two goods, i and j, then the marginal rate of substitution (MRS) between the ith and jth goods is arrived at by dividing the Qith good by the Qjth good first order conditions. This yields an optimal solution that equates the MRSij with the price ratio of the goods.

Hence: $MRS_{ij} = \frac{MU_i}{MU_j} = \frac{P_i}{P_j}$ (3.2)

Consequently, solving the consumers' choice problem yields a Marshallian demand function of the form:

$$Q_i^* = f\left(P_i, y / \beta\right) \qquad \forall_i \tag{3.3}$$

where Q_i^* is the optimal consumption point of the ith good. The demand function is condition on the utility function parameter and constraints as previously defined, as such any change in the utility function ultimately re-defines the demand function and optimal solution set.

3.3.1.1 A Summary of Meat Demand Studies

The previous section contains the derivation of the Marshallian demand function using the constrained optimization method. This section reviews existing research on meat demand. The aim is to assist in picking out appropriate and relevant variables and functional form to be used in this study. Furthermore, the demand function agreed upon base on the review will be inculcated in the oligopoly/oligopsony model and the elasticities produced will be compared with previous studies and used to update existing research. A summary on previous demand studies is given in table 3.4.

From the review in table 3.4, it is obvious that the ad hoc approach to modeling demand is preferred to the systems approach. For convenience of estimation and tractability, linear demand models are best suited (Dhar and Cotterill, 2002). This is in agreement with the section on analytical tool previously. Since the demand equation is going to be used as part of a larger system of equations, it is pertinent that a simple and less restrictive type of the ad hoc demand equations be used so too many assumptions are not imposed on the elasticity results. Note that it is assumed that prices of all other goods remain exogenous to this equation and those changes in the beef market and other goods are independent of each other.

In this context therefore, the linear demand equation becomes appropriate compared to the double or semi-logarithm functional form equations because the last two functional forms make overly restrictive assumptions on the elasticity results. It is believed that flexible functional forms allow a number of system approaches to modeling consumer behaviour and satisfies perfect aggregation conditions over consumers (Moschini and Meilke, 1989). The best option with the least restriction would have been the Box-Cox functional form except for its associated rigor of estimation and functional form simulation.

In the next section, a conceptual background for the supply equation used in this study is developed. This also involves the review of previous supply studies and a careful selection of appropriate methods and techniques to be used in order to achieve stated objectives.

Table 3.1 Summary of previous studies on meat demand

Author/Year/Country	*Explanatory variables*	*Functional form*
Tryfos and Tryphonopoulos (1973)/ Canada	*Annual prices of beef pork, chicken, lamb and veal, and income*	*Linear specification*
Hassan and Katz (1975)/ Canada	*Annual prices of beef, pork, chicken, veal, lamb and turkey*	*[illegible] unrelated regression of linear*
Hassan and Johnson (1976)/ Canada	*Annual Beef and pork price, a time trend and income*	*Double log specification*
[illegible] (1977)/ U.S.	*Annual [illegible]*	[illegible]
Hassan and Johnson (1979, 1983)/ Canada	*Quarterly data on beef pork, chicken, turkey and veal. Income and seasonal dummies*	*Uses the generalized Box-Cox transformation on the different functional forms*
[illegible]/ U.S. meat demand	*[illegible] pork prices and quantities, and income*	*[illegible] demand function in [illegible] unrelated [illegible]*

[illegible]	[illegible]	[illegible]
Wohlgenant (1985)/ U.S.	*Beef, poultry, pork and fish prices, and income*	*Fourier series that allows for shift of demand curve over time.*
Young [illegible]/ Canada	*Beef, pork chicken and turkey* [illegible]	[illegible] *transformations of the linear, double-log, linear log and Box-cox to tes* [illegible]
Coleman and Meilke (1988)/ Canada and the U.S.	*Beef and pork prices and income*	*Linear specification*
Moschini and Meilke (1989)/ U.S. meat demand	*Quarterly data on beef, chicken, fish and pork prices and their disappearance, income and* [illegible]	[illegible]
Atkins, Kerr and McGivern (1989)/ U.S.	*Beef, pork and chicken consumption and price data*	*Linear specification to capture structural change*
[illegible] *(1991)/ Canada and Australia*	*Beef, pork and chicken for Canada, and Beef, pork and lamb for Australia including advertising and meat expenditure for both* [illegible]	[illegible] *double log expenditure functions*
Alston and Chalfant(1991)/ U.S.	*Analyzed Beef, poultry, pork ands fish demand using prices and income*	*Linear, double log, static and first differentiated versions of the LA/AIDS and Rotterdam.*
[illegible] *(1991)/ Canada*	[illegible] *beef, pork chicken and fish pri* [illegible]	[illegible]
Chen and Veeman (1991)/ Canada	*Quarterly data on beef, pork, chicken and turkey prices, income measure and seasonal variables*	*Dynamic specification of the AIDS model*
[illegible] *(1991)/ Canada*	[illegible] *consumption using their price an* [illegible] *data and season* [illegible]	[illegible] *AIDS model*
Goddard and Cozzarin (1992)/ Canada	*Annual data on Beef, pork and chicken prices and advertising expenditure as a demand shifter*	*Translog function and AIDS model*
[illegible] */ U.S.*	[illegible] *demographics, advertising* [illegible]	[illegible]
Moschini and Vissa (1993)/ Canada	*Beef, pork and chicken quantities and prices, income and seasonal*	*Rotterdam specification*

	dummies.	
Eales (1996)/ Canada	*Meat demand using quarterly beef, pork and chicken prices and quantities data.*	*[illegible] differential AIDS*
Xu and Veeman (1996)/ Canada	*Meat demand using quarterly quarterly beef, pork and chicken prices and quantities data*	*Linear AIDS and Rotterdam model*
Marsh (2003)/ U.S. retail beef demand	*Annual data on beef demand index, prices and quantities, by-product prices and an index of food marketing [illegible]*	*[illegible] structural model of demand in a system of equations*
Chern et al (2003)/ Japan household meat demand	*Cross sectional data on beef, pork, poultry, ground beef, ham, sausage and bacon prices and quantities; household food expenditure data and some demographics.*	*Linear functions of single equation models and AIDS*
Lomeli (2005)/ Canada	*Time series and cross sectional demand data on beef, pork and chicken prices and quantities, income, health and advertisement variables [illegible]*	*[illegible]*

3.3.2 Cattle Supply Response

In this section, the conceptual framework of cattle supply and supply responses is reviewed. This is followed by a review of previous studies on cattle supply and supply responses. This exposition and review of literature will help in developing a framework upon which this study will be based. Finally, a specification of the supply model to be used in this study is given.

An important aspect of modeling livestock slaughter industry is an approximation of the underlying dynamics, which are difficult to be effectively specified. Cattle supply responses is an onerous task because of the difficulty in understanding the factors of producer expectations from market signals, technological change, biological production lags and other random variables.

The cattle industry production system is characterized by a cycle of approximately 11 years. Rosen et al. (1994) showed that regular cycles in the stock of cattle emerge as a prediction to a competitive environment where rational; profit maximizing ranchers make economic decisions in a dynamic environment with uncertainty. It therefore becomes clear that cattle cycle is the result of producers' responses to shocks in the environment, coupled with lengthy biological lags.

After breeding of heifers, calves are born mostly in the spring and are weaned from their mothers in the fall when they are about four to six months. At this point producers face an important management decision of either to sell them off to the feedlots for finishing and slaughter (consumption good) or retain them (heifers) as breeding stock (capital good). Steers are easily sold to the feedlot sector since they are destined for slaughter. Before being sent to the feedlot for slaughter, they go through a process called finishing for six months where they are put on various rations of pasture and harvested forage before they are sold to feedlots. At the feedlots they are fattened with highly concentrated grain meals for another six months before slaughter. This makes it approximately two years after the birth of the calf, which means that expansion of breeding herd takes about two years.

This stock expansion ultimately reduces fed cattle prices, and such effects are transmitted through the feedlot to cow-calf businesses through decline in feeder cattle prices. At this point cow culling increases and heifer retention decreases, which consequently reduce the breeding herd size. Fed cattle marketing is reduced so as to build the breeding herd again after a certain period of adjustment. All things being equal, prices begin to appreciate after the period of adjustment and the cattle cycle starts all over again.

It therefore implies that the expansion of breeding herd is as a result of the production lag while the contraction is stimulated by market forces (basically price movements). It is worthy of note too that exogenous shock such as bad weather and other environmental factors as well as a dynamic response to price could influence the cattle cycle.

It is important to know that producer price expectations play a vital role in the analysis of cattle supply response because of the lag between production decisions and the actual realization of output. Adjustments in supply and inventories are costly and take time, and production decisions are based on expected future cattle and feed prices and/or feed availability that are presumably a function of past observed prices (Rucker et al. 1984).

A way of modeling this phenomenon is either through partial adjustment and / or adaptive expectation models (Nerlove, 1965), which are used to justify the use of lagged dependent variables as right hand side variable in supply equations. These distributed lags could be geometrically or polynomial distributed, or rationally distributed. Each of these distribution types has its merits and demerits based on the weights regime on past prices.

With the geometric distributive lag (GDL), weighing on past prices declines geometrically and the coefficient on the lagged dependent variable is an indication of the length of response due to changes in past prices. Therefore the bigger the coefficient, the longer it takes for past price responses to affect current period price and production decision, and vice-versa. The polynomial distributive lag (PDL) structure lags variables using a polynomial weighing scheme where the price responses may follow a higher and unlimited power order of different lengths. It has the advantage of allowing for both decreasing and increasing weighting effect of past price while the GDL only assumes declining weights. The rational distributive lag approach allows for different lag processes, i.e., GDL or general PDL.

Under the expectation hypothesis, naïve expectation has been characterized as an unsophisticated projection based on guesses or on mechanical extrapolation of current prices. It is however used in agricultural supply models and is often associated with the "efficient market hypothesis" (Sulewski et al., 1994). In its formulation, expected price is the actual price in the previous period.

Hence:

$$P^e{}_t = P_{t-1}$$

where

$P^e{}_t$ = expected price at time t and

P_t = actual price at time t.

Still within the expectation hypothesis, is the Nerlovian (1958) adaptive expectation model where adjustment in price expectations are assumed to be proportional to last period's expectation error. Thus:

$$P^e{}_t - P^e{}_{t-1} = \xi\left(P_t - P^e{}_{t-1}\right)$$

$$P^e{}_t = P^e{}_{t-1} + (1-\xi)\left(P_{t-1} - P^e{}_{t-1}\right) \qquad \xi \in [0,1] \tag{3.4}$$

where ξ = the co-efficient of expectation.

It is assumed that producers form expectations of prices for a commodity whose market is characterized by the following supply function:

$$Q_t = \beta_0 + \beta_1 . P^e{}_t + U_t \tag{3. 5}$$

where:

$Q_t \equiv$ *current period quantity* sup *plied,*
$\beta_i \equiv$ sup *ply eqaution parameters and*
$U_t \equiv$ *disturbance term*

Substituting the expected price equation into the quantity supply equation produces a supply equation that shows that current supply is a function of current price and all past price, and a dependent lagged supply variable. Thus:

$$Q_t = \beta_0 \xi + \beta_1 \xi P_t + (1-\xi) Q_{t-1} \tag{3.6}$$

The partial adjustment hypothesis as put forward by Nerlove (1958) is somewhat the same as that of the expectation hypothesis except for the fact that current supply is modeled as depending on current period price. After a few manipulations and substituting the supply equation into the expectation process, a current period supply equation that looks similar to the adaptive expectation equation emerges.

Marsh (1984) observed that the reason for inconsistencies in supply elasticities and why previous empirical findings have indicated conflicting results may have reflect failure to model both short-run and long-run cattle marketing decisions because they are never homogeneous. This is due to the lag in cattle production; hence short-run cattle marketings are relatively flexible because the timing of sales can be altered in response to expected price changes. The result in the short run is that we may observe a negative relationship between price and quantity supplied (i.e., a downward sloping supply curve) and a positive relationship in the long run as the larger breeding stocks produce more animals destined for the market. This result agreed with Jarvis (1974); Paarsch (1985) and Rosen et al. (1994)

The Nerlovian adaptive expectation model helps to estimate both short and long run elasticities in a manner where cattle producers' response to past price changes within an adaptive expectation framework. In line with Jarvis (1974) suggestion, cattle are viewed as capital goods; as such beef price changes will have two opposing effects on producer's decisions. Firstly, an increase in beef prices will cause producers to expect higher prices in the future, which will make them to want to increase herd size so as take advantage of this future price increase. This is the investment demand. Secondly, the price increase will encourage cattle producers to sell cattle immediately to profit from the current high price, otherwise know as the consumption demand phase.

Martin and Haack (1977) observed that total beef supply is affected by the size of the calf crop in the previous years, the time cattle are placed on feed, the length of time they remain on feed (which directly affects their weight), number of calves slaughtered for veal, number of heifers placed in to breeding herd and the rate of cow culling from herd. Also the supply responses in different geographical regions may vary due to local production possibilities and economic conditions.

Some of the variables determining price expectations are likely to be outside of the market in which producers with breeding herd sell their calves. If producers are "rational", fed beef and corn prices could partially determine producers' calf price expectations. Feeder prices are a direct indicator of the demand for feeder as an output to ranching operations. On the other hand, prices of fed beef and corn jointly indicate the profitability of feeding operations and the expectations of future fed beef prices, and hence the expected future for steers and heifers, and the expected opportunity cost of retention of heifers as breeders rather than placing them in the market for feeders.

Furthermore, since low quality beef prices from cows follow the movement of fed beef prices closely, changes in fed beef prices are likely to influence production decision to keep or cull older cows. It is therefore right to say that lagged feed, fed cattle prices and the breeding stock in previous periods affect fed-cattle supply response. Synonymous to short and long-run effects, current prices are expected to produce negative responses to fed-cattle supply while past prices are expected to produce positive responses. The breeding or total inventory to a larger extent is expected to have a direct relationship with fed-cattle marketing. Also, both feed and calves prices are expected to affect breeding herd size. Feed prices have an influence through the future derived demand for feeder cattle as it may affect cattle inventories as a proxy for feed costs in the production of feeder cattle. Of course, feeder cattle prices share a positive relationship with fed cattle prices, and the breeding herd size by implication is positively related to feeder prices.

Two other variables hypothesized to have important effect on beef supply at the processing plants is the level of capacity utilization of plants and the BSE variable. It is hypothesized that a low level of capacity utilization due to less labour (mechanical or manual), or lack of supply of raw materials (fed cattle and cows) from the farm could affect cattle and fed beef supply. Low capacity utilization from other sources other than lack of supply from producers may also force producers to reduce supply of fed cattle and increase their breeding herd and total inventory. Excess capacity has been the problem at the farm level due to the BSE crisis, which has hindered the movement of cattle over thirty months (mostly cows) across the Canada-U.S. border. Since everything is modeled within an adaptive expectation framework, it is expected that past capacity utilization rates affects present decision making process for the processors and consequently, the producers.

3.3.2.1 A *Summary of Previous Cattle and Beef Supply Studies*

In this section, an attempt is made to summarize previous studies on supply and supply response in the beef-cattle industry with most emphasis to North America. Following the numerous studies reviewed, it is evident that there are two, different components of fed and mature cattle supply, which have to be modeled separately for a better understanding of the production sub-sector. The feedlot and cow-calf are seen to be related through the feeder stock. This important relationship is accounted for by estimating a price linkage equation of steer and heifer price to feeder price. The feedlot is left with the task of deciding how many animals to feed and at what weight are they supposed to be sold. This is done in consideration of the prevailing market price for fed and non-fed cattle, feeder prices, feed price and breeding herd size. Therefore in line with these reviewed studies, the equations that are going to be defined are: slaughter steer and heifer supply, slaughter cow and bull supply, breeding herd size or inventory, feeder price and price linkage equations.

Table 3.2 Summary of Previous Studies on Supply and Supply Response Studies

[illegible]	[illegible]	[illegible]
Reutlinger (1966)/U.S partial adjustment model	*Steer supply as a function of beef-corn price ratio and beef and cow inventory lagged one period. Heifer supply as a function of beef-corn rice ratio and cow inventory lagged one period. Cow supply as a function of beef-corn price ratio and current cow inventory.*	*Price responses were found to be positive for steers and negative for cows.*
[illegible]	[illegible]	[illegible]
Tryfos (1974)/Canada/ partial adjustment model	*Total cattle slaughter plus exports as a function of current beef cattle inventory and current inventory lagged one period. Current inventory as a function of live cattle price, index of feed price and beef cattle inventory lagged one period.*	*Cattle supply was negatively related to current inventory and positive to lagged inventory. Inventory was negatively related to feed price, and positive to cattle price and lagged inventory.*
[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]
Nelson and Spreen (1978)/U.S. / price expectations	*Cattle slaughter as a function of price trend, cattle on feed by weight class and placements on feed.*	*Generally, slaughter is directly related to change in price if the direction of price change in the interval of t-1 to t is different from that of t-1 to t-1. slaughter is also inversely related to price change if the most recent price change is the continuation of a trend.*
[illegible]	[illegible]	[illegible]

[redacted]	[redacted]	[redacted]
Goddard (1979)/ Western and Eastern Canada and U.S./ GDL for Western Canada and the U.S., and PDL for Eastern Canada.	*Most specifications and equations were in consonance with Martin and Haack (1977). They however included lagged hog price in cow and bull supply equation. The opportunity cost of breeding herd expansion was captured by including hog price and interest rate in the inventory equations. Beef production as a function of cow and bull slaughter, breeding herd inventories lagged ten quarters, feed price lagged two quarters, steer prices*	
[redacted]	[redacted]	[redacted]
Rucker, Burt and Lafrance (1984)/ Montana and the U.S./ rational expectation	*For Montana, beef breeding herd and all cattle inventory equations as a function of hay production lagged one and two periods, beef-corn price ratio, previous corn price, calf prices lagged for two periods, and expected inventory lagged for 2 periods as well as two auto-regressive disturbance terms. For the U.S. case, all variables were same as the Montana case except that hay production was omitted.*	*Breeding herd response to price ratio was found to be positive, and the beef-corn price ratio variable performed better that corn price in partially explaining the changes in breeding herd.*

[illegible]	[illegible]	[illegible]
Marsh (1994)/ U.S./ Partial adjustment model	*Fed cattle market supply as a function of current and one period lagged fed cattle price, current feeder cattle and feed prices and two successive periods lagged, number of days slaughter plants open in the month, inventory of cattle on feed and a lagged dependent variable. Feeder cattle placed on feed regressed on current and one period lagged fed cattle price, inventory of cattle on feed, current corn price, current and one period lagged feeder price and a lagged dependent variable. Both equations had autocorrelation parameters to the third period.*	*Results showed switching supply elasticities from negative to positive over time, and couldn't find evidence of short-run supply been fixed. Cattle marketing decisions in the short run affected by capital versus consumption goods criteria, whereas long term decisions reflect major resource adjustments and technological changes affecting cattle placements*
[illegible]	[illegible]	[illegible]
Granfield et al (1999)/ Western and Eastern Canada and U.S./ GDL for Western and eastern Canada and U.S	*Breeding herd inventory as a function of time trend, interest rate lagged two periods, feeder calf lagged two periods, and a lagged dependent variable. Slaughter cow and bull supply as a function of feeder calf prices lagged one period, breeding herd inventory lagged one period, dairy cow inventory lagged one period, and a lagged dependent variable. Slaughter steer and heifer supply a function of steer price lagged two periods, feed price lagged one period, breeding herd inventory lagged two periods, and a lagged*	*Found supply response to be positive with respect to price for slaughter steer and heifer, but negative for cow and bull slaughter.*

	period, breeding herd inventory lagged two periods, and a lagged dependent variable. Carcass weight as a function of slaughter steer price, feed price, the ratio of slaughter cow and bull supply, and a lagged dependent variable. Feeder calf price transmission a function of slaughter steer price, feed price, and a lagged dependent variable. Slaughter cow price transmission a function of feeder calf price, and a lagged dependent variable.	
[redacted]	[redacted]	[redacted]

Simple linear ad hoc functional forms are used as seen in most of the previous studies and explanatory variables are going to be included to reflect cow-calf and feedlot producers' decision making process aimed at profit maximization. Price of inputs and output are going to be modeled under an adaptive expectation framework or partial adjustment approach.

Feeder (stocker) prices constitute one of the major inputs of the feedlot operation. The prices of feeders depend on the feedlot operators' expected price of fed and mature cattle, and the cost of feeding the calves to mature weight. They are also affected by the supply of animals from cow-calf operations. Therefore, feedlot operators calculate how much they will pay for a calf based on their feed cost and the price they expect for finished cattle. This concept, which is reflected in the modeling, makes it clear that the price of feeder calves at any point in time would be determine mainly by the feedlot sector. In each of the regional equation, current feeder price linkage equation is regressed on current steer price; current feed price and a lagged dependent variable. Quarterly dummies are also included to account for seasonality in prices.

The general idea on breeding inventories is that cow-calf operator's decisions on adjustment in herd size, which are seen as capital goods, is primarily dependent on the expected price of the output (feeder calves). Inventories are adjusted in two ways: either by regulating the rate at which heifers are added to the herd or the rate at which cows are culled or slaughtered. Martin and Haack (1977) observed that the expansionary phase of the beef cycle involves an increase in the net addition of heifers and a decline in the rate of cow and bull slaughter, with the opposite happening during a liquidation phase. The estimation approach in this study is to try and relate breeding inventory for each region as a function of expected feeder calves prices, and a one quarter lagged dependent variable. Interest rate to account for the opportunity cost of herd expansion is also added as in Cranfield (1999). The GDL approach is used.

Cow and bull supply decision by the cow-calf operations could be of two kind and, hence two different outcomes. The first one is if expectation of increased feeder calf prices induces the retention of the breeding herd longer, then we would expect the rate of cow and bull supply to fall and a consequent increase in breeding herd. This is bound to have an inverse relationship with feeder prices. The second component consists of cow and bull culling following ageing. This is a routine practice and does not depend on feeder prices but defines the cattle cycle. Cow and bull supply for each region is therefore regressed against current feeder calf prices, cow and bull inventory lagged, and the dependent variable lagged one quarter and seasonal dummy variables.

For heifer and steer supply response, it is assumed that between birth and slaughter of cattle (approximately two year period) there is a considerable flexibility in the decisions of beef producers as to the age and weight at which cattle are slaughtered. This period of flexibility in decision is responsible for producing either negative or positive elasticity results with respect to steer and heifer prices (Reutlinger, 1966). At the early stages of feedlot operations[18] as steer prices increases, it is expected that cattle would be placed on feed earlier and less would be slaughtered as veal, and vice versa when prices decreases. Hence we would expect to find a positive relationship between current supply and steer prices lagged one to two years. If for any reason, increase in steer prices is observed while cattle are already placed on feed, there will be then an incentive to hold steers to heavier weights. This would result into a negative relationship between steer supply and steer prices. We would expect a stronger negative relationship for heifers since they have the option of either selling or adding them to the breeding herd[19].

Increased feed prices in the early period would make more cattle slaughtered as veal in their early stages. This would affect feeder price and increase heifer supply making the short run relationship between increase feed price and supply to be positive. In more distant lagged periods would mean that more cattle would be placed on feed later, hence a negative relationship between distant lagged prices and current supply is expected. Each region's steer and heifer supply is regressed on steer and heifer prices, breeding herd inventories, feed price and the dependent variable lagged one period, and seasonal dummies. This estimation is done using a GDL procedure.

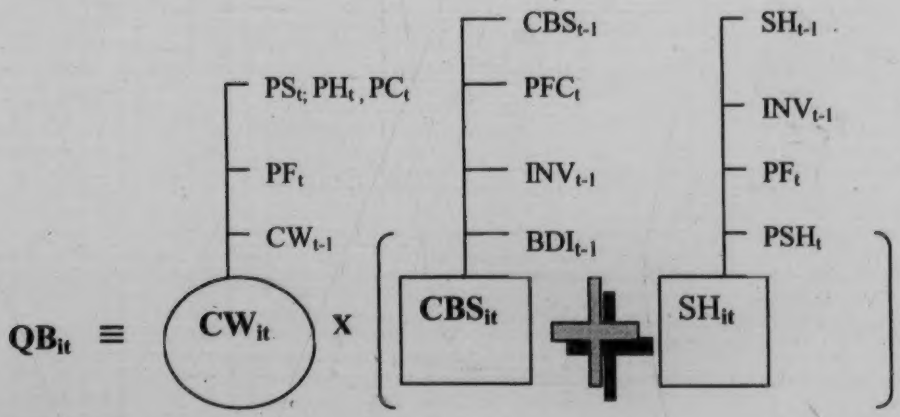
The figure below summarizes the effects of different variables and the linkages in the model.

---

[18] Calves can be left on pasture or placed on feed at feed lots and allowed to mature before slaughter, or slaughtered as veal

[19] Feeder prices are positively related to steer prices and breeding stock are positively related to feeder prices, hence, the incentive for higher heifer retention at the cow-calf operation in to the breeding herd.

Figure 3.1 A Sketch of the Beef Supply Response Model



$$\boxed{INV_{it}} = PFC_t + PF_t + INV_{t-1}$$

$$\boxed{PFC_{it}} = PS_t + PF_t + PFC_{t-1}$$

For a detailed definition of the variables used see appendix I. The diagram above shows a picture of the interaction at the farm level involving the cow-calf and feedlots, which determines the supply of cattle. It reveals that steer (PS) and feed (PF) prices are directly or indirectly in every equation, hence their importance. The identity, total supply (QB) is the sum of cow and bull (CBS), and steer and heifer slaughter (SH) multiplied by the average of their respective carcass weight (CW). Carcass weight increases with an increase in steer price carcass weight lagged one quarter, and decreases with a decrease in current feed price. Cow and bull slaughter is expected to decline with an increase in feeder cattle prices (PFC), increase with beef cow and dairy inventories lagged one quarter, and increase with increase in cow price. Whereas feeder cattle price is expected to increase with an increase in steer price within that period and decrease with an increase in current feed price. Current steer and heifer supply is expected to increase with an increase in steer and heifer prices. An inverse relationship is expected between steer and heifer supply and current feed price, and a direct relationship is also expected between steer and heifer slaughter and breeding inventory in the previous quarter and their price lagged one quarter. The breeding inventory is expected to vary directly with the feeder cattle price and indirectly with feed price.

3.3.3 Processor / Retailer Behavioural Equations

In developing the input/output market power empirical model, the cost function and profit function of the firm will have to be specified in accordance to some preset conditions. Since linear aggregation is going to be assumed across regions, then a cost function suitable and one that satisfy this condition has to be used. In the previous chapter, it was shown that the Gorman Polar form cost function as used by virtually all the literature on market power studies is suitable since it is a linearly homogenous cost function with a constant return to scale restriction. It is also imperative that this cost function be defined to allow for both regional and a comprehensive North American marginal cost equation. Thus the cost function assumed for the regional industry is the Generalized Leontief as presented in Appelbaum (1982).

For Western Canada:

$$C^{WC} = \sum_i \alpha_{8,i} . w_i^{WC} + QB1.\sum_i \sum_j \beta_{8,i,j} . \left(w_i^{WC} . w_j^{WC} \right)^{1/2}$$

For Eastern Canada:

$$C^{EC} = \sum_i \alpha_{9,i} . w_i^{EC} + QB2.\sum_i \sum_j \beta_{9,i,j} . \left(w_i^{EC} . w_j^{EC} \right)^{1/2}$$

For the U.S.:

$$C^{US} = \sum_i \alpha_{10,i} . w_i^{US} + QB3.\sum_i \sum_j \beta_{10,i,j} . \left(w_i^{US} . w_j^{US} \right)^{1/2}$$

Where C^k = total cost in the kth region,

QBk = beef production in the kth region, with k= 1, 2 and 3,

w_i^k = the ith input/ output price in the kth region,

α, β = parameters to be estimated,

i, j = index for input used, 1= live cattle, 2= labour and 3= capital.

Taking first order conditions of the regional cost functions, the regional cost functions become:

$$\frac{\partial C^{WC}}{\partial QB1} = \sum_i \sum_j \beta_{8ij} . \left(w_i^{WC} . w_j^{WC}\right)^{1/2} \qquad (3.7)$$

$$\frac{\partial C^{EC}}{\partial QB2} = \sum_i \sum_j \beta_{9ij} . \left(w_i^{EC} . w_j^{EC}\right)^{1/2} \qquad (3.8)$$

$$\frac{\partial C^{US}}{\partial QB3} = \sum_i \sum_j \beta_{10ij} . \left(w_i^{US} . w_j^{US}\right)^{1/2} \qquad (3.9)$$

Therefore, a composite North American cost function will consist of all three cost functions brought together with some other assumptions[20] made. That is:

$$C^{NA} = C^{WC} + C^{EC} + C^{US}$$

However, certain assumptions will have to be made with regard to which price to use that will reflect the North American market. Since most of the industry (meat packing and processing) and its inputs is concentrated in the U.S., the study assume that input prices are determined in the U.S. as such a special price relationship as in Cranfield (1995) is developed.

$$w_{i,j}^{WC} = \delta_{i,j}^{WC} + \lambda_{i,j}^{WC} . w_{i,j}^{US} = a$$

$$w_{i,j}^{EC} = \delta_{i,j}^{EC} + \lambda_{i,j}^{EC} . w_{i,j}^{US} = b$$

δ, λ = parameters.

The North American cost function becomes:

$$\begin{aligned} C^{NA} = & \sum_i \alpha_{8,i} . a_i + Q1 . \sum_i \sum_j \beta_{8,i,j} . \left(a_i . a_j\right)^{1/2} + \\ & \sum_i \alpha_{9,i} . b_i + Q2 . \sum_i \sum_j \beta_{9,i,j} . \left(b_i . b_j\right)^{1/2} + \\ & \sum_i \alpha_{10,i} . w_i^{US} + Q3 . \sum_i \sum_j \beta_{10,i,j} . \left(w_i^{US} . w_j^{US}\right)^{1/2} \end{aligned}$$

---

[20] The North American beef and cattle industry is restricted to only the US and Canada with the exception of Mexico.

One of the conditions for linear aggregation is to ensure that all regional cost functions are equal. That is, a restriction should be in place to enforce this constraint.

Thus: $\beta_{8,i,j}\left(a_i . a_j\right) = \beta_{10,i,j} . w_i^{US} . w_j^{US}$

$$\beta_{9,i,j}\left(b_i . b_j\right) = \beta_{10,i,j} . w_i^{US} . w_j^{US}$$

Solving for the coefficients $\beta_{8,i,j}$ and $\beta_{9,i,j}$ yields the following:

$$\beta_{8,i,j} = \beta_{10,i,j} . \frac{w_i^{US} . w_j^{US}}{a_i . a_j} = m$$

$$\beta_{9,i,j} = \beta_{10,i,j} . \frac{w_i^{US} . w_j^{US}}{b_i . b_j} = n$$

Incorporating this restriction into the composite cost function produces:

$$C^{NA} = \sum_i \alpha_{8,i} . a_i + \sum_I \alpha_{9i} . b_i + \sum_i \alpha_{10i} . w_i^{US} + \sum_i \sum_j m\left(a_i . a_j\right)^{1/2} . QB1$$
$$\sum_i \sum_j n . \left(b_i . b_j\right)^{1/2} . QB2 + \sum_i \sum_j \beta_{10i,j} . w_i^{US\,1/2} . w_j^{US\,1/2} . QB3$$

By collecting like terms and rearranging the equation, it becomes:

$$C^{NA} = \sum_i \alpha_{8,i} . a_i + \sum_I \alpha_{9i} . b_i + \sum_i \alpha_{10i} . w_i^{US} + (QB1 + QB2 + QB3)$$
$$\sum_i \sum_j \beta_{10i,j} . w_i^{US\,1/2} . w_j^{US\,1/2}$$

Thus the North American marginal cost function becomes:

$$\frac{\partial C^{NA}}{\partial(QB1 + QB2 + QB3)} = \sum_i \sum_j \beta_{10i,j} . \left(w_i^{US} . W_j^{US}\right)^{1/2} \tag{3.10}$$

Based on the production-theory approach of Gohin and Guyomard (2000)) and its extension by Anders (2005), the regional model parameterizes the retail and packing/processing industry's oligopoly and oligopsony equilibria. It is worthy of note that the problem of the profit maximizing processing and retail industry is to choose optimal quantities, Qi, which maximizes the regional industry's profits while considering the economic environment as dictated by the demand and supply functions specified.

The profit function of the yth firm in the processing or retail industry with respect to beef and beef products is then:

$$\Pi_i^j = \sum_{i=1}^{S} p_i.Q_i^d - \sum_{i=1}^{S} w_i.Q_i^j - C_i^j(Q_i, w_i) \qquad \text{j} = 1,\ldots,\text{s}. \qquad (3.11)$$

Where p_i is the consumer (retailers) price of beef (boxed beef) and w^i is the price of meat (cattle) input at the retailers' (wholesale) market level. Q^d is the industry's retail/wholesale demand function and Q^j is the firms input quantity demand. The profit function above assumes that beef and cattle are demand related. Profit maximization under oligopoly and oligopsony yields the following first-order conditions.

$$p_i - w_i - \frac{\partial C^j(.)}{\partial Q_i^j} + \sum_{s=1}^{S}\left(\frac{\partial p_s}{\partial Q_i}\right)\cdot\left(\frac{\partial Q_i}{\partial Q_i^j}\right).Q_i^j - \sum_{s=1}^{S}\left(\frac{\partial w_i}{\partial Q_i}\right)\cdot\left(\frac{\partial Q_i}{\partial Q_i^j}\right).Q_i^j = 0 \qquad (3.11a)$$

The issues of aggregation of simultaneous equation models have been largely discussed and used by, for example, Cranfield (1995), Schroeter and Azzam (1991), and Wann and Sexton (1992). Hence, additional assumptions concerning the conjectural variation as well as the cost function have to be maintained. The aggregate industry cost function is specified in the Gorman Polar form with constant and identical marginal costs and fixed costs possibly varying among retailers. Therefore (3.11) can equivalently be written as:

$$p_i - w_i - \frac{\partial C}{\partial Q_i} = -\left(\frac{1}{Q_i}\right)\cdot\left[\sum_{i-1}\theta_i\eta_i.p_i.Q_i - \theta_{ii}\varepsilon_i.w_i.Q_i\right], \qquad (3.11b)$$

where $\eta_i = \left(\frac{\partial Q_i}{\partial w_i}\right)\cdot\left(\frac{w_i}{Q_i}\right)$ is the price elasticity of final demand at the retail/wholesale level, $\varepsilon_i = \left(\frac{\partial Q_i}{\partial p_i}\right)\cdot\left(\frac{p_i}{Q_i}\right)$ is the elasticity of supply measured at the meat processors/producers market level and $\theta_i = \theta_{ii} = \Sigma\ (\partial Q/\partial qi)^*(qi/Qi)$ are average elasticities of conjectural variation with respect to the final good output (θ_i) and the wholesale/producer factor input (θ_{ii}) as downstream consumers/retailers and upstream meat processors/producers.

To capture the effect of changing economic conditions on market structure in this study, we specify θ_i *and* θ_{ii} with structural equations. Using an extended Cranfield's specification we defined θ_i *and* θ_{ii} as a function of the relevant Herfindahl index, time trend and capacity utilization rates of the processing industry. Thus, the structural equation for θ_i *and* θ_{ii} is:

$$\theta_{ij} = \alpha_i + \beta_i CU_j + \beta_i HFINDX_j + \beta_i T + \beta_i .D_5 + \beta_i .FPS_j \qquad (3.12a)$$

$$\theta_{iij} = \alpha_{ii} + \beta_{ii} CU_j + \beta_{ii} HFINDX_j + \beta_{ii} T + \beta_{ii} .D_5 + \beta_{ii} .WPS_j \qquad (3.12b)$$

where θ_i, α_i *and* β_i are coefficients to be estimated on the oligopoly side and θ_{ii}, α_{ii} *and* β_{ii} are coefficients on the oligopsony side. j = 1, 2 and 3 representing Western and eastern Canada and the U.S. HFINDX ≡ Herfindahl index, CU is the capacity utilization rates. FPS and WPS are farm and wholesale prices for the different regions, and T is time trend. D_5 is the dummy variable capturing the effect of BSE.

Herfindahl index (HI) is a generally preferred measure of concentration because it takes into account the number of firms and relative distributional shares of the market held by the firms, not just the largest few. It takes the entire size distribution of enterprise into account. A priori, concentration measures should be inversely related to the number of firms and positively related to the magnitude of size inequalities. By squaring the shares, large firms gets a relatively larger weight than small firms. Thus the HI is more appropriate in measuring the degree of inequality, without reference to the actual numbers of enterprise.

$$HI = \sum_{i=1}^{n} x_i^2$$

where n = number of enterprise and x_i is the share of industry shipment, value added or employment accounted for by the ith enterprise.

The Herfindahl-Hirshman index (HHI) as used by the American government is the product of HI and 10,000. The Department of Justice and the Federal Trade Commission consider markets to be non-concentrated when the value of the HHI is below 1,000, moderately concentrated when HHI is between 1,000 and 1,800, and highly concentrated when HHI is above 1,800 (U.S. Department of Justice and Federal Trade Commission, 1997).The Herfindahl index is included as a measure of industry concentration. In general, the more concentrated an industry is, the more oligopoly/oligopsony power is expected to exist.

Lopez (2002) argues that increased concentration may result in increased collusion among firms. This collusion is expected to contribute to increased oligopoly/oligopsony power. We also expect that the capacity utilization coefficient will have an inverse or negative relationship with the CV elasticity. Time is included as a proxy variable for technical change or improvement in the beef industry over the sample period. Technical improvement in beef product processing is expected to increase the degree of market power and profit margin by cutting processing costs. Therefore, we expect $\beta_{253}>0$. The BSE trade restriction variable, which is to take care of the effect of border closing in 2003, is expected to also affect firms profit maximization process in terms of how they cope with costs and drops/increase in cattle input supply. Steer demand and supply prices by the processor are also expected to affect the competition in the industry. Changes of this nature will certainly affect the competition type and market conduct of the industry.

3.4 North American Beef-Cattle Model Schematic

Before the empirical models in the next chapter, two stylized schematic models of the North American cattle and beef industry are presented pre and post BSE to provide a vivid picture of the entire modelling process. It is an extension of the prior diagram (fig.3.1) on supply response and it introduces the issue of trade in beef and cattle within the regions and the complex interaction processes.

The stylized schematic presentation in figure 3.1 represents the relationship among consumers, processors and producers in the North American beef/cattle industry prior BSE. The model is constructed under the assumption that Canada and the US is the representative of the North American beef cattle industry and that trade flows, and market signals among the three levels of the market are interconnected between the two countries.

As will be seen in figure 3.2, Canadian beef prices are assumed to be determined by U.S. beef prices since U.S. seems to be the major export market to Canada and the largest producers of both cattle and beef in North America. This relationship affects Canadian beef and cattle production, and demand and trade with the U.S. Principally, U.S. processor decision affects US beef prices, slaughter cattle and fed-cattle prices, which then affects US feeder prices at the backgrounder or feed lot level and this determines the supply response from the cow-calf level in the long run. This long run supply response feeds back fed and mature cattle into the live cattle market that subsequently influences slaughter volume, prices and some level of beef production in the U.S. Prices at the U.S. feedlots affects Canadian fed cattle prices, which also affects feeder prices at the feedlots or backgrounder.

Feeder prices in Canada affects prices at the cow-calf level and also begin the supply response process in Canada, which in turn feeds mature and fed cattle into the live cattle market. Finally, Canadian fed-cattle prices affect live cattle trade between the U.S. and Canada; influences Canadian cattle slaughter, and consequently affect production and trade in Canada.

Conversely in figure 3.3, at the instance of the first BSE case, both levels at the feedlots and retail levels that linked trade in quantity and prices between the two countries were broken in the first three months of BSE. The farm level remained the same since the supply response process and production is a long term process hence, adjusted cannot be made radically. However, processors due to excess capacity problems in Canada from the farm level dictated prices and the result was a plummeting fed cattle price from the farm level. They also send price signals to the retailers since beef consumption even increased within this period in Canada (Statistics Canada, 2004) as seen in Table 3.3. The US market apparently remained the same only having marginal effects, with the farm level sending price signals to the processors. The U.S. therefore had to increase its supply from other importing countries. After the first three months trade was only allowed for beef and the interaction in terms of trade was only between the last two levels of the market.

The same trend is observed in Canada during the first three months because beef consumption remained positively favourable, so processors in Canada still maintained their high profit margin as seen in Table 3.1 where capacity utilization are seen to be higher in Canada than the U.S. The third circuit court ruling of July of 2005 re-introduced the movement of cattle under thirty months (UTM) thereby creating some amount of relieve to farmers

This complex price and trade relationships is modelled and price linkage equations that relates the two countries are developed. This is to ensure that any shock emanating from one point, which has the tendency of sending resonating effects to other levels, is been captured.

Figure 3.2 Flowchart of the North American Beef Cattle Industry Before BSE

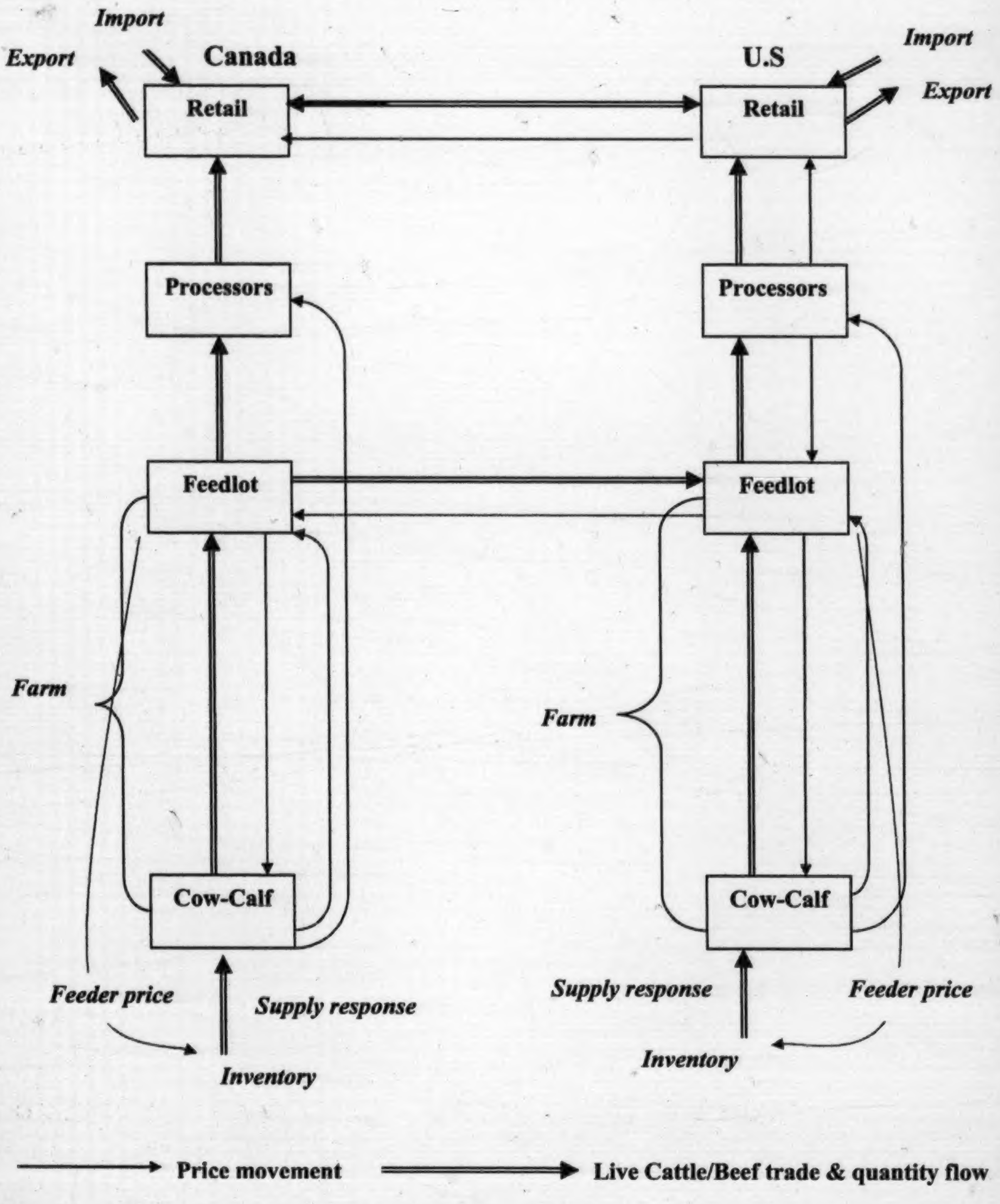
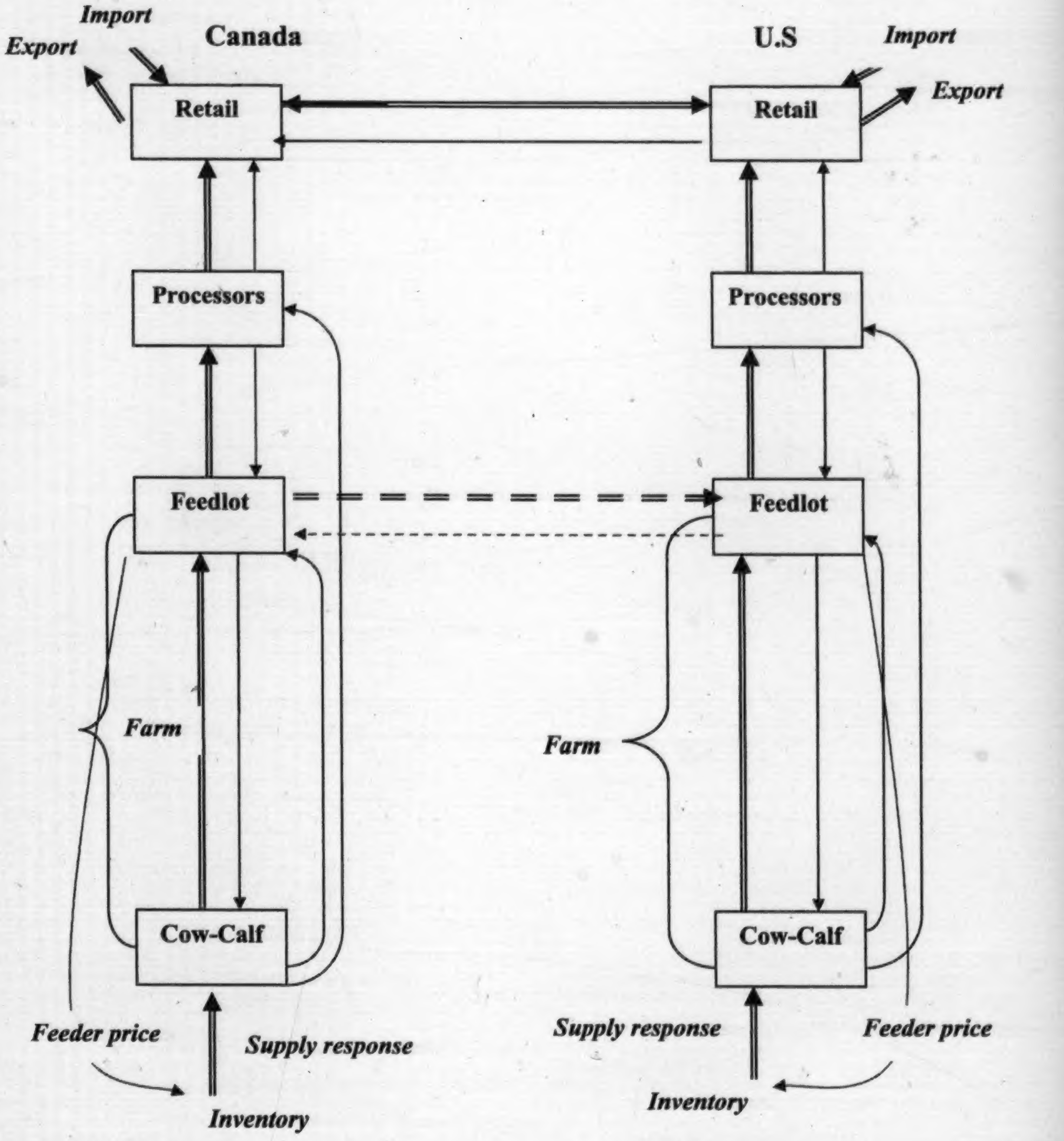


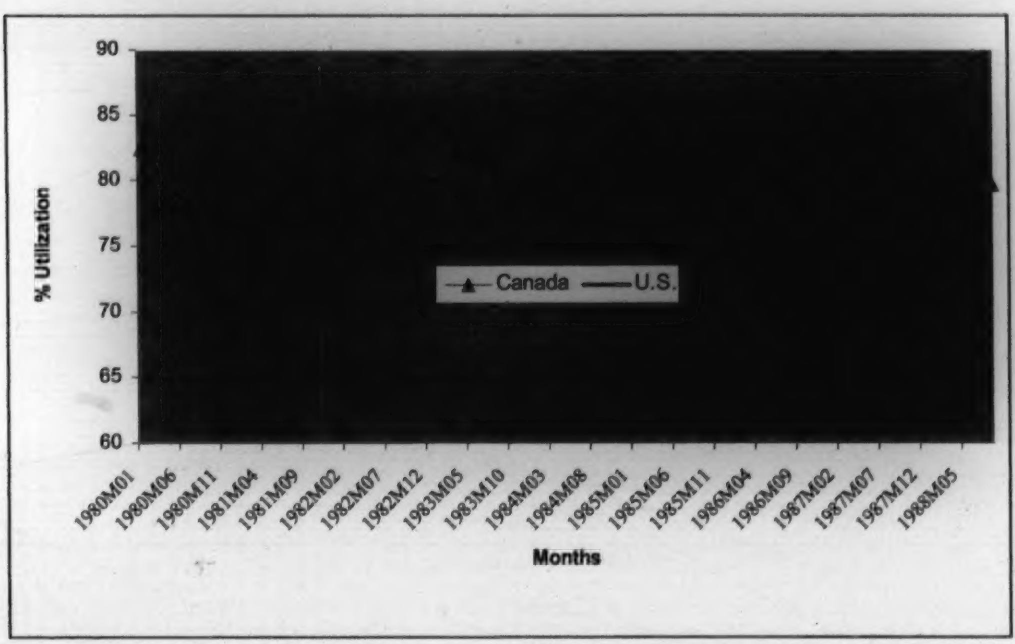
Figure 3.3 A Schematic of the North American Beef Cattle industry During BSE



⟶ Price movement ⟹ Live Cattle/Beef trade & quantity flow

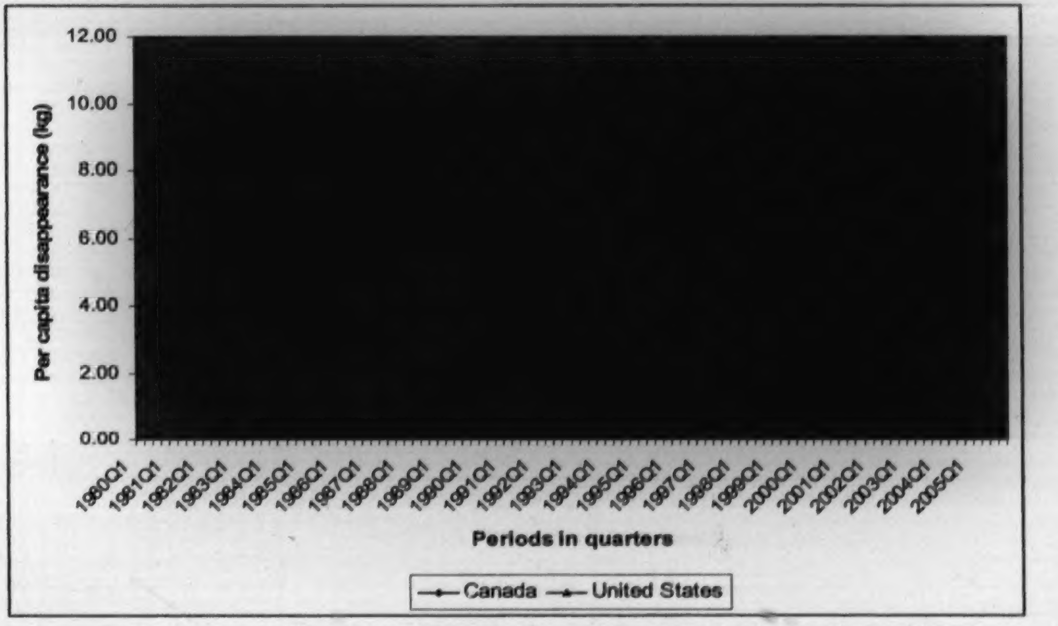
Note: Broken lines represent partial trade due to ban on cattle over thirty months (OTM)

Table 3.3 Food manufacturing industries capacity utilization rates in Canada and The US (1980-2005)



Sources: Statistics Canada and the U.S. Federal Reserve Statistical Release G.17, 2005.

Table 3.4 Per capita beef disappearance in Canada and the U.S. (1980-2005)



Source: Several issues of the Canada Livestock and Meat Trade Report (1980-2005)

3.5 Market Closing Indentities and Price Linkage

The modeling process is completed by specifying market clearing equilibrium conditions or binding constraints. These are in form of accounting relationship that would help close the modeling process (figures 3.1, 3.2 and 3.3) and make model simulations easy. Market clearing equilibrium or closing identities for the retail and farm levels are shown below.

The following accounting identity is used to relate per capita beef disappearance to total beef disappearance for the three regions under consideration.

Canada beef disappearance:

$$\mathrm{BD12 = PCBD12\ X\ POP12}$$

U.S. beef disappearance:

$$\mathrm{BD3 = PCBD3\ X\ POP3}$$

where $\mathrm{BD_i}$ (i=12 and 3) are total beef disappearance for Western and Eastern Canada, U.S. and Canada as a whole, respectively. PCBD12 and PCBD3 are per capita beef disappearance for Canada and the U.S. respectively. POP12 and POP3 are population figures for Canada and the U.S. respectively.

Retail market closing identities are developed using total beef disappearance figures. Canadian retail market equilibrium is used to determine net beef exports from Canada to the U.S. while the U.S. market clearing identities are used to determine net beef export from the U.S. to the rest of the world (ROW) as shown below

Canadian retail market equilibrium:

$$BD12 = QB1 + QB2 - \Delta STOCK12 + EXB123 - IMB123 + EXB124 - IMB124$$

U.S. retail market equilibrium:

$$BD3 = QB3 - EXB123 - IMB123 + EXB34 - IMB34 + \Delta STOCK3$$

where ΔSTOCK12 and ΔSTOCK3 are change in beef stock in Canada and the U.S. respectively. $\mathrm{QB_i}$ is regional beef production. EXB123, IMB123 are beef export and import from Canada to the U.S. EXB34, IMB34 and EXB124, IMB124 are beef export and import from the U.S. to the rest of the world (ROW), and from Canada to the rest of the world, respectively.

Farm level market equilibrium identities are used to determine net live cattle exports and imports from Western and Eastern Canada to the U.S.

Western Canada steer and heifer farm level equilibrium:

$$QS1 = SS1 + SH1 + NTSC13$$

Eastern Canada steer and heifer farm level equilibrium:

$$QS2 = SS2 + SH2 + NTSC23$$

U.S. steer and heifer farm level equilibrium:

$$QS3 = SS3 + SH3 - NTC13 - NTC23$$

Western Canada cow and bull farm level equilibrium:

$$QS4 = CBS1 + NTSC13$$

Eastern Canada cow and bull farm level equilibrium:

$$QS5 = CBS2 + NTSC23$$

U.S. cow and bull farm level equilibrium:

$$QS6 = CBS3 - NTC13 - NTC23$$

where QS_i (i=1, 2, 3) and NTC13 and NTC23 are the slaughter supply for western and eastern Canada and the U.S. respectively, and net live cattle exports from western and eastern Canada to the U.S. respectively. SS_i, SH_i, CBS_i, are regional slaughter figures for steer, heifer, cow and bull.

To determine slaughter volumes for steer and heifers slaughter by the processor, another identity is defined using total slaughter or demand of slaughter cattle. The identity is presented below for three regions as:

For western Canada:

$$CS1 = SHS1 + CBS1$$

For eastern Canada:

$$CS2 = SHS2 + CBS2$$

For the U.S.:

$$CS3 = SHS3 + CBS3$$

Where where CS_i (i=1, 2 and 3) is the demand for slaughter cattle in western and eastern Canada, and the U.S., respectively. SHS1, SHS2 and SHS3 are slaughter number for steer and heifers in western Canada, eastern Canada and the U.S., respectively

Finally, the amount of beef produced for each region is determined by multiplying total slaughter for each cattle sex and class by their respective carcass weights.

Western Canada beef production:

$$QB1 = (SHS1 * PROPS1 * CWS1) + (SHS1A * PROPH1 * CWH1) + (CBS1 * CWC1)$$

Eastern Canada beef production:

$$QB2 = (SHS2 * PROPS2 * CWS2) + (SHS2A * PROPH2 * CWH2) + (CBS2 * CWC2).$$

U.S. beef production:

$$QB3 = (SHS3 * PROPS3 * CWS3) + (SHS3A * PROPH3 * CWH3) + (CBS3 * CWC3)$$

Canada beef production:

$$QB12 = (QB1) + (QB2)$$

CW_i (i=1, 2, 3) are average regional carcass weight figures for western and eastern Canada and the U.S. respectively. Other variables are as previously defined in appendix I.

These identities and models estimated in this chapter are used in a simulation model to validate the entire model structure as presented in figure 3.1.

In order to close the model completely for simulation, more equations or identities need to be developed or estimated in order to account for all endogenous variables to use in the model simulation. Therefore four price equations are developed and estimated for steers in the three regions and cow and bull price for the U.S.

For western Canada:

$$PS1 = \alpha_{28} + \beta_{281} \cdot PSH1 + \beta_{282} \cdot PS1(-1) + \beta_{283} \cdot Q2 + \beta_{284} \cdot Q3 + \beta_{285} \cdot Q4$$

For eastern Canada:

$$PS2 = \alpha_{29} + \beta_{291} \cdot PSH2 + \beta_{292} \cdot PS2(-1) + \beta_{293} \cdot Q2 + \beta_{294} \cdot Q3 + \beta_{295} \cdot Q4$$

For the U.S :

$$PS3 = \alpha_{30} + \beta_{301} \cdot PSH3 + \beta_{302} \cdot PS3(-1) + \beta_{303} \cdot Q2 + \beta_{304} \cdot Q3 + \beta_{305} \cdot Q4$$

For the US price of cow and bull:

$$PCB3 = \alpha_{31} + \beta_{311} \cdot PSH3 + \beta_{312} \cdot PCB3(-1) + \beta_{313} \cdot Q2 + \beta_{314} \cdot Q3 + \beta_{315} \cdot Q4$$

Where PS is the price of steers and α, β are coefficients to be estimated. Other variables are as previously defined.

Since we are imposing linear aggregation on the North American composite estimation model, we have to relate prices across the regions in one unit- the U.S. dollars. Therefore, as in Cranfield (1995), Canadian prices of beef and live cattle, meat packer and retailer wage rates and capital are regressed on their corresponding prices in the U.S. The spatial price relationships equations are presented below.

Canada-U.S. retail beef price linkage equation:

$$RPB12 = \alpha_{11} + \beta_{111}.T + \beta_{112}.\frac{RPB3.CPI3.ER}{CPI12} + \beta_{113}.NBE12 + \beta_{114}.RPB1(-1) \qquad (3.13)$$

Western Canada-US steer and heifer and cow and bull price linkage equation:

$$PSH1 = \alpha_{13} + \beta_{131} \cdot T + \beta_{132} \cdot \frac{PSH3.CPI3.ER}{CPI12} + \beta_{133} \cdot NCE1 + \beta_{134} \cdot PSH1(-1) \qquad (3.14a)$$

$$PCB1 = \alpha_{14} + \beta_{141} \cdot T + \beta_{142} \cdot \frac{PCB3.CPI3.ER}{CPI12} + \beta_{143} \cdot NCE1 + \beta_{144} \cdot PCB1(-1) \qquad (3.14b)$$

Eastern Canada-US steer, heifer and cow price linkage equation:

$$PSH2 = \alpha_{15} + \beta_{151} \cdot T + \beta_{152} \cdot \frac{PSH3.CPI3.ER}{CPI12} + \beta_{153} \cdot NCE2 + \beta_{134} \cdot PSH2(-1) \qquad (3.15a)$$

$$PCB2 = \alpha_{16} + \beta_{161} \cdot T + \beta_{162} \cdot \frac{PCB3.CPI3.ER}{CPI12} + \beta_{163} \cdot NCE2 + \beta_{164} \cdot PCB2(-1) \qquad (3.15b)$$

where CPI_i for i=12, and 3, represents the all item consumer price index for Canada and the U.S. respectively. ER is the Canada-US exchange rate and NBE_i and NCE_i for i= 1, 2, are the net beef and net live cattle exports from western and eastern Canada to the U.S. respectively. All other variables are as previously defined.

The retail beef price linkage equation 3.13 tries to relate Canada to U.S. prices, net beef export and a lagged price variable to capture past trade and price effects on current period prices. The net beef export variable is included to capture changing trade volume effect on transportation cost. Since prices have been spatially linked among regions, the next task will be to derive the input, both material and non-material, demand functions using Shepard Lemma from the regional cost functions. This study considered live cattle, labour and capital demand for beef processors.

3.5.1.1 *Feeder Calf Price Linkage equations*

Stocker prices are very instrumental in the cow-calf sector and in determining inventories and the entire decisions of the feedlot operators. Feedlot demand for feeder calves depends on their marginal value product which depends upon the current prices of steers and the cost of feeding them to market weight. It is assumed that response to feed cost is considered not immediate because most feed are home grown. Seasonal dummies are included and a time trend, and lagged dependent variable of the previous quarter.

Western price of feeder steers:

$$PFC1 = \alpha_{38} + \beta_{381}.PS1 + \beta_{382}.PF1 + \beta_{383}.T + \beta_{384}.D_2 + \beta_{385}.D_3 + \beta_{386}.D_4 + \beta_{387}.PFC1(-1) \tag{3.18a}$$

Eastern price of feeder steers:

$$PFC2 = \alpha_{39} + \beta_{391} \cdot PS2 + \beta_{392} \cdot PF2 + \beta_{393} \cdot T + \beta_{394} \cdot D_2 + \beta_{395} \cdot D_3 + \beta_{396} \cdot D_4 + \beta_{397} \cdot PFC(-1) \tag{3.18b}$$

U.S. price of feeder steers:

$$PFC3 = \alpha_{40} + \beta_{401}.PS3 + \beta_{402}.PF3 + \beta_{403}.T + \beta_{404}.D_2 + \beta_{405}.D_3 + \beta_{406}.D_4 + \beta_{407}.PFC3(-1) \tag{3.18c}$$

where all variables are as previously defined for all regions.

3.6 Summary

This chapter tries to develop the theoretical underpinnings surrounding this whole study, by building a conceptual model for consumers, processors and producers marketing of cattle and beef in the North American cattle-beef industry. The North American beef processors' actions are captured using a conjectural variation model that estimates both oligopoly and oligopsony market power. Cost economies measures were also defined for the processors' market level to help differentiate between market power and cost advantage. Prior to that, the analytical techniques and estimation procedure to be used were analyzed and the periodicity of the entire study was determined.

Single ad hoc demand equation was assumed, and cattle producer supply response was assumed to take an adaptive price expectation framework encompassing both long and short run responses to cattle production cycle. A schematic framework of the entire composite model was presented and market closing identities developed for the closure of the entire model. This is to help establish market equilibrium at the different market levels and to make easy the simulation model that would be used to validate results and test for different welfare measures. Literatures on past research were reviewed in terns of estimation procedure, functional forms used, variables considered and final results attained.

Chapter four consist of the empirical model specifications and estimations where all the conceptualized models and issues raised in this chapter are put into their respective empirical perspective.

Chapter Four: DATA AND EMPIRICAL MODELS

4.1 Background

In this chapter, the data and sources will be discussed followed by the specification and estimation of our model as conceptually presented in the previous chapter. The model, which will simultaneously consider the joint estimation of oligopoly and oligopsony power, will consist of consumer demand for retail beef, farm supply function for cattle, cattle inventory equations, feeder cattle price and price linkage equations, a factor demand behaviour derived from the Gorman Polar Leontief cost function , and processors'/ retailers' profit maximization equations. This econometric model will be used to satisfy the objectives of this study. This chapter will contain the specification and estimation of the econometric models that will incorporate all these equations. The conjectural variation parameter represents the index of market structure or competition type (Wann and Sexton 1992). The Lerner Index (LI) represents the degree of market power and the cost economy component is captured by the relationship between the marginal and average costs estimation.

4.2 DATA

The importance of accurate and consistent data in any empirical investigation of market power and price spread behaviour cannot be over emphasized as seen in its theory and previous studies. Collection of appropriate data needed to calculate spreads and price-cost margins, and the use of proper explanatory variables is very important (Scott, 1983). An explicit explanation of the data and its sources and how the different price variables are derived is presented in appendix I.

For the sake of valid comparison across the different market levels, coupled with the fact that beef carcasses go through a lot of processing before the final product that is sold at retail stores is achieved, an acceptable standard becomes necessary. Following Scott's (1983) estimation and method, the chilled and trimmed fresh carcass, prior to any further processing is used as a standard unit of product for constructing cattle price spreads. At this point, it is important to maintain consistency in pricing the same product at any level of the market. All prices of cattle at all levels will be expressed in Canadian cents per pound of chilled carcass at the packer's level.

4.2.1 Farm Level Data

Price series for A1/A2 steers and heifers, and D1/D2 cows at Toronto and Calgary were collected for the last week of the month. Data for 1980-1990 were obtained from the Canada Livestock and Meat Trade Report, and 1991-2005 data were obtained online from the AAFC website. In order to adjust farm prices of cattle in dollars per hundred weights live to a chilled carcass equivalent, dressing and cooler shrink percentages were used.
A1/A2 steer/heifer or D1/D2 cow carcass equivalent for Ontario/Alberta = Monthly prices in $/cwt live + dressing percentage and cooler shrink percentage.

A constant value for both dressing and cooler shrink percentages as used by Scott (1983) was used due to lack of varying historic data. Specific warm carcass dressing percentage according to grades and associated cooling percentage[21] and the 1976 beef inquiry report[22] provided chilled carcass dressing percentage for steers, heifers and cows (see table below).

Table 4.1: **Prices of Chilled Beef carcass equivalent**

A1/A2 Ontario steer carcass equivalent = A1/A2 steer price in cents/cwt live + **0.558** (dressing % & cooler shrink %).

A1/A2 Alberta steer carcass equivalent = A1/A2 steer price in cents/cwt live + **0.553** (dressing % & cooler shrink %).

A1/A2 Ontario heifer carcass equivalent = A1/A2 steer price in cents/cwt live + **0.541** (dressing % & cooler shrink %).

A1/A2 Alberta heifer carcass equivalent = A1/A2 steer price in cents/cwt live + **0.537** (dressing % & cooler shrink %).

A1/A2 Ontario cow carcass equivalent = A1/A2 steer price in cents/cwt live + **0.498** (dressing % & cooler shrink %).

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[21] Sourced from Dr. R. Osborne, University of Guelph, Department of Animal Science.

[22] Richard Daniels (1976). Farm to Retail Price Spreads for Beef in Canada. Commision of inquiry into the marketing of beef and veal , Report 2, Ottawa.

A1/A2 Alberta cow carcass equivalent = A1/A2 steer price in cents/cwt live + **0.485** (dressing % & cooler shrink %).

The gross farm price is used in the farm supply equations for steer, heifer and cow.

4.2.2 Packer Level Data

Data for the six major cuts (brisket, shank, flank, ribs, square cut chuck, loin and hip) that constitute the carcass weight of a beef carcass as recognized by the Canadian Beef Information Centre (2005) were used to calculate the wholesale prices. The Montreal wholesale prices of beef cuts as reported by the Canada Livestock and Meat Trade Report (1980-1990), and 1991-2005 from the AAFC website.

To build a composite carcass from these cuts, we use the following formula:

Packer (wholesale) price in cents/lb chilled carcass weight = major cut price in Cents/lb X (percentage composition of cut in carcass X respective carcass weight).

Respective constant percentages of cuts used are as follows:

- Brisket = 6 % of carcass by weight
- Shank = 4 % of carcass by weight } Full brisket 16%
- Flank = 6 % of carcass by weight
- Square cut Chuck = 29% of carcass by weight
- Rib = 11 % of carcass by weight
- Loin = 21 % of carcass by weight
- Hip = 23 % of carcass by weight

4.2.3 Retail Level Data

Percentage yield from a chilled carcass estimated for all retail cuts from beef carcass is used to estimate retail carcass value. Due to restrictions imposed by data availability, six retail cuts from Statistics Canada CANSIM II database[23] are used for both Ontario and Alberta. These cuts are: sirloin steak, round steak, prime rib roast, blade roast, stewing beef and ground beef. These six retail cuts account for 48% of the carcass weight. Daniel's (1976) unpublished correlation research of 21 beef cuts as used in Scott (1983) is used to develop a weighing scheme allowing the six cuts to approximate the total retail value of the carcass. Daniel correlated 87 time series observations of the six cut prices with twenty one beef cuts in Toronto.

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[23] Cansim II tables 3260012: Average retail prices for food and other selected items

The resultant weighing scheme for high quality beef (A1and A2 steers & heifers) retail cuts for Toronto and Calgary is given below:

Sirloin steak	18.53 % of the packers carcass weight
Round steak	10.62 % of the packers carcass weight
Prime rib roast	6.74 % of the packers carcass weight
Blade roast	12.54 % of the packers carcass weight
Stewing beef	20.40 % of the packers carcass weight
Hamburger	6.72 % of the packers carcass weight
	75.55%

The remaining 25% made up of bones (13%), fat (10%) and shrink (2%).

For low quality cow beef (economy beef), data on cutting test from Steinberg of Montréal is correlated using the D. Ricard's method to arrive at a weighting scheme for retail cuts in Toronto and Calgary as shown below:

Sirloin steak	15.22 % of the packers carcass weight
Round steak	12.74 % of the packers carcass weight
Prime rib roast	6.16 % of the packers carcass weight
Blade roast	15.88 % of the packers carcass weight
Stewing beef	1.57 % of the packers carcass weight
Hamburger	25.40% of the packers carcass weight
	77.05%

Retail prices in cents/lb in chilled packer carcass = retail quoted price of cut in cents/lb X (% composition of cut in carcass X respective Carcass weight). This is the net price of beef devoid of by-product prices and used in the retail demand equation.

By-product prices from CANFAX were divided by respective carcass weights for Alberta and Ontario steers and multiplied by a 100 to arrive at the values in cents/ pound chilled carcass packer value. Data from 1980 to 1991 is obtained from Canada Livestock and Meat Trade Report, 1992-2005 are high price by-product values in $ per head steer reported by CANFAX.

In the U.S. case, the spreads is already calculated in US cents per pound retail weight as found in the USDA, ERS website[24] on meat price spreads data set, which was converted to cents/Canadian pound chilled carcass weight by multiplying by the respective dressing percentages and exchange rate.

U.S. Dressing percentages are calculated from data obtained from the USDA, ERS Red Meat Yearbook (94006)[25] excel spreadsheet using the formula:

[26]Dressing Percentage for steer, heifer or cow = Carcass Weight of steer, heifer or cow/

Live Weight of cattle X 100

However, constant values that have been in use by the USDA and Agricultural Marketing Service of the USDA are 63% for steers and heifers and 47% for cows.

Carcass weights data from 1980-1996 are obtained from the Canada Livestock and Meat trade report; 1997-2005 data is obtained from CANFAX.

4.3 Model Specification and Empirics

This section will consist of the specification of the models used to achieve the objectives of this study. This includes retail beef demand and cattle supply in the regional markets; regional and North American beef processor/retailers' oligopoly/oligopsony power, and a cost economy model. This study developed retail equations for both the U.S. and Canada consisting of quarterly variables that are important in determining the interaction at the retail level for all regions, and for the entire North American market. The inventory equation is modeling the cow-calf sector at the farm level with specific emphasis on the prices of feeder cattle and feed prices taking into account the lagged period for herd expansion while accounting for adaptive price expectation. This is because of the time taken from breeding decision to the long gestation period of nine months, to birth and weaning of calves.

Cattle supply equations will model the entire farm level (cow-calf and feedlot) since the supply of cattle could be at any of these levels. However, it mostly happens at the feedlot operations. Feeder cattle prices and carcass weights are also estimated as stated in order to complete the supply response process. It also includes the supply of beef from the processor to the retailers in the downstream markets. Price interaction and transmission equations will help depict the different relationships in terms of price movements and product flow with the assumption that the U.S. is the major market hence, the price setter.

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[24] for an explanation on this see: http://www.ers.usda.gov/briefing/foodpricespreads/meatpricespreads/

[25] See details from: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354

[26] See http://ars.sdstate.edu/MeatSci/May99-1.htm; http://www.safarix.com/013046256X/ch23lev1sec5

Finally, the oligopoly/oligopsony model for both regional and North American estimations will be at the processor level to help determine the market structure and market power in the industry. This will however consist of the processors' interaction with the farm level and retail level in either direction using marginal cost, conjectural elasticity and cost economies equations. All these equations will contain variables that are relevant to the entire modeling process and in accordance with existing literature as presented in the preceding chapters.

4.3.1 The Retail Demand Specification

Just as in the studies reviewed in the last chapter and in a deliberate attempt not to involve a strong restriction of constant elasticity across the sample period, a single linear equation is used as the functional form for the demand specification. The per capita beef demand therefore consist of consumer retail price of beef, per capita disposable income and exogenous demand shifters. Following other research reviewed, the Marshallian demand function as developed previously with prices and income as explanatory variables is used in this study. Although the conceptual specification showed that all prices of goods in the economy should be included in the demand equation which is not practical, this study will only use the price of beef (Marsh, 1992; 2003), pork and chicken as been used by most of the studies reviewed as demand shifters. Per-capita disposable income is used as a measure of income and the composite price index for all items is used as a deflator of the other prices and income so as to account for all goods in the economy. The consumer price index (CPI) of all other item as used satisfies the basic demand condition of homogeneity of degree zero in prices and income. The use of these two variables imposes the assumption of non-seperability of the demand function. In addition, a time variable is added to capture disappearance trend, and seasonal dummy variable are also included in order to capture seasonality in beef demand.

Therefore the regional per capita retail beef demand is presented in the following equations.

For Canadian retail beef demand:

$$\begin{aligned} PCBD12 = \alpha_1 + \beta_{11}.T + \beta_{12}.PCD1 + \beta_{13}.RPB1 + \beta_{14}\ RPP1 + \beta_{15}.RPC1 + \\ \beta_{16}.D_1 + \beta_{17}.D_2 + \beta_{18}.D_3 + \beta_{19}.D_5 + \beta_{110}.PCBD1(-1) \end{aligned} \tag{4.0a}$$

For the U.S. retail beef demand:

$$\begin{aligned} PCBD3 = \alpha_3 + \beta_{31}.T + \beta_{32}.PCD3 + \beta_{33}.RPB3 + \beta_{34}\ RPP3 + \beta_{35}.RPC3 + \\ \beta_{36}.D_1 + \beta_{37}.D_2 + \beta_{38}.D_3 + \beta_{39}.D_5 + \beta_{10}.PCBD3(-1) \end{aligned} \tag{4.0b}$$

where PCBDj (j= 12, 3) is the per capita beef disappearance in Canada and the U.S. respectively. T is time trend, PCDi is deflated per capita disposable income; and RPBi, RPPi, RPCi are deflated beef, pork and chicken price respectively. D_i (i = 2, 3, 4)are seasonal dummies for spring, summer and fall with winter left out to be used as a reference variable in terms of result analysis. The dependent lagged variable is to capture habit formation in beef consumption due to changes in lifestyle and health considerations, changing demographics and relative meat prices (Moschini, 1989; Marsh, 2003). It is expected that the signs of the coefficients under *a priori* conditions will be negative for time (as seen in figure 1.1) and beef prices. Pork and chicken prices, and per capita disposable income are expected to have positive coefficients signifying that those other meats are substitutes to beef and that beef is a normal good. Chavas (1983), Cranfield and Goddard (1999), Lomeli (2005), among others had similar findings. The seasonal dummies coefficients may vary and will depend on weather changes as it affects people's consumption over the sampled period. We also expect our habit formation coefficient by definition to carry a positive sign with demand.

4.3.2 Live cattle and wholesale beef supply specification

According to Azzam (1996; 1997), production of grain-fed cattle is assumed to require three major inputs- corn, calves (feeder cattle), and transportation services. Cranfield (1995) did not only agree with Azzam but also added breeding beef and dairy cow inventory, and included the effect of government programs on cattle supply. He also added that cattle supply and supply response depends on the relationship between biological production lags and producers ability to respond to market signals. Cranfield's (1995) review, points out that most studies have used linear ad hoc functional forms and explanatory variables are included to reflect producers' expectations regarding future profitability. In accordance with the schematics of the model, cattle supply decision starts at the cow-calf enterprise with ranchers deciding on their breeding herd inventory. Therefore it becomes pertinent to specify a beef inventory equation for all regions taking into account the fact that production is based on expected returns from the animal input.

Therefore, this study will draw from Martin and Haack (1977), Cranfield (1995) and Azzam (1996; 1997) models to build the entire supply response model for all regions from beef herd inventory for beef cow, supply equations for fed steer and heifer, and cow and bull; feeder calve price response and price linkage, and carcass weight equations.

4.3.2.1 Steer and heifer, and cow and bull supply functions

Following the conceptualized model, the supply of fed steer and heifer in the processing sector, and cow in the cow-calf operation is empirically modelled. Cow and bull supply contains cow and bull price, beef cattle and dairy inventory, lagged dependent variable, seasonal dummies and time trend variables. Steer and heifer supply is regressed against steer and heifer prices, current feed price, breeding inventory lagged one quarter, a time trend and seasonal dummies, and a lagged dependent variable for each region.

Western Canada cow and bull supply:

$$\begin{aligned} CBS1 = {} & \alpha_4 + \beta_{41}.BDI1(-1) + \beta_{42}.INV1(-1) + \beta_{43}.T + \beta_{44}.PC1 + \\ & \beta_{45}.D_2 + \beta_{46}.D_3 + \beta_{47}.D_4 + \beta_{48}.D_5 + \beta_{49}.CBS1(-1) \end{aligned} \tag{4.1a}$$

Eastern Canada cow and bull supply:

$$\begin{aligned} CBS2 = {} & \alpha_5 + \beta_{51}.BDI2(-1) + \beta_{52}.INV2(-2) + \beta_{53}.T + \beta_{54}.PC2 + \\ & \beta_{55}.D_2 + \beta_{56}.D_3 + \beta_{57}.D_4 + \beta_{58}.D_5 + \beta_{59}.CBS2(-1) \end{aligned} \tag{4.1b}$$

U.S. cow and bull supply:

$$\begin{aligned} CBS3 = {} & \alpha_6 + \beta_{61}.BDI\ 3(-1) + \beta_{62}.INV3(-2) + \beta_{63}.T + \beta_{64}.PC3 + \\ & \beta_{65}.D_2 + \beta_{66}.D_3 + \beta_{67}.D_4 + \beta_{68}.D_5 + \beta_{69}.CBS3(-1) + \beta_{610}.PC3 \end{aligned} \tag{4.1c}$$

Western Canada steer and heifer supply:

$$SH\ 1 = \alpha_{41} + \beta_{411}\ .PSH\ 1 + \beta_{412}\ .INV\ 1(-1) + \beta_{413}\ .PF\ 1 + \beta_{414}\ .D_2 + \beta_{415}\ .D_3 + \beta_{416}\ .D_4 + \beta_{417}\ .D_5 + \beta_{418}\ .SH\ 1(-1) \quad (4.2a)$$

Eastern Canada steer and heifer supply:

$$SH\ 2 = \alpha_{42} + \beta_{421}\ .PSH\ 2 + \beta_{422}\ .INV\ 2(-1) + \beta_{423}\ .PF\ 2 + \beta_{424}\ .D_2 + \beta_{425}\ .D_3 + \beta_{426}\ .D_4 + \beta_{427}\ .D_5 + \beta_{428}\ .SH\ 2(-1) \quad (4.2b)$$

U.S. steer and heifer supply:

$$SH\ 3 = \alpha_{43} + \beta_{431}\ .PSH\ 3 + \beta_{432}\ .INV\ 3(-1) + \beta_{433}\ .PF\ 3 + \beta_{434}\ .D_2 + \beta_{435}\ .D_3 + \beta_{436}\ .D_4 + \beta_{437}\ .D_5 + \beta_{438}\ .SH\ 3(-1) \quad (4.2c)$$

where CBS and SH are cow and bull, and steer and heifer supply respectively. BDI and PFC are beef cow and dairy inventories and price of feeder cattle respectively. INV and PF are breeding inventory and feed price respectively. Other variables are as previously defined. All other variables except the prices of slaughter cattle are considered supply shifters.

4.3.2.2 *Breeding Herd or Beef Inventory Equations*.

Beef cow inventory is modeled as feeder cattle price lagged one quarter, lagged dependent variable due to adaptive price expectation, lagged interest rate to account for the opportunity cost of herd expansion and a time trend. Thus, the regional beef cow inventory equations are presented as follows:

$$INV_{it} = \alpha_i + \beta_{i1}.T + \beta_{i2}.PFC_i + \beta_{i3}WK_i + \beta_{i4}.INV_i(-1) + \beta_{i5}.PF_i \quad (4.3)$$

where i (i=1,2,3) represents West, East and the U.S. regions and WK_i for i=12, 3 is the prime business interest rate for Canada (west or east) and the U.S. respectively. Other variables are as previously defined.

Beef cow inventory for western Canada:

$$INV1 = \alpha_{26} + \beta_{261} \cdot T + \beta_{262} \cdot PFC1(-1) + \beta_{263} \cdot WK12(-1) + \beta_{264} \cdot INV1(-1) + \beta_{265} \cdot PF1(-1)$$
(4.4a)

Beef cow inventory for Eastern Canada:

$$INV2 = \alpha_{27} + \beta_{271} \cdot T + \beta_{272} \cdot PFC2(-1) + \beta_{273} \cdot WK12(-1) + \beta_{274} \cdot INV2(-1) + \beta_{275} \cdot PF2(-1)$$
(4.4b)

Beef cow inventory for the U.S.

$$INV3 = \alpha_{28} + \beta_{281} \cdot T + \beta_{282} \cdot PFC3(-1) + \beta_{283} \cdot WK3(-1) + \beta_{284} \cdot INV3(-1) + \beta_{285} \cdot PF3(-1) \quad (4.4c)$$

4.3.2.3 *Carcass Weights Equations.*

Carcass weights are related to the short run prices of slaughter cattle because they give an indication of how much beef an animal produces, hence beef production. As reviewed earlier, carcass weights are a product of how much feed is available and consumed by cattle. Therefore cattle output and feedlot profits are reflected in the carcass weight, which is affected by cattle and feed prices. Unlike Martin and Haack (1977) and Cranfield and Goddard (1999), this study will estimate carcass weights for steers, heifers and cows.

To estimate this effect, this study used as explanatory variables, current steer, heifer, cow and feed prices, a time trend variable, seasonal dummies and a one quarter lagged carcass weight. This is estimated for all regions.

Western Canada steer carcass weight:

$$\begin{aligned} CW1_S = \alpha_{29} + \beta_{291}.PS1 + \beta_{292}.PF1 + \beta_{293}.T + \\ \beta_{294}.D_2 + \beta_{295}.D_3 + \beta_{296}.D_4 + \beta_{297}.CW1_S(-1) \end{aligned} \quad (4.5a)$$

Western Canada heifer carcass weight:

$$\begin{aligned} CW1_H = \alpha_{30} + \beta_{301}.PH1 + \beta_{302}.PF1 + \beta_{303}.T + \beta_{304}.D_2 \\ + \beta_{305}.D_3 + \beta_{306}.D_4 + \beta_{307}.CW1_H(-1) \end{aligned} \quad (4.5b)$$

Western Canada cow carcass weight:

$$\begin{aligned} CW1_C = \alpha_{31} + \beta_{311}.PC1 + \beta_{312}.PF1 + \beta_{313}.T + \beta_{314}.D_2 \\ + \beta_{315}.D_3 + \beta_{316}.D_4 + \beta_{317}.CW1_C(-1) \end{aligned} \quad (4.5c)$$

Eastern Canada steer carcass weight:

$$\begin{aligned} CW2_S = \alpha_{32} + \beta_{321}.PS2 + \beta_{322}.PF2 + \beta_{323}.T + \\ \beta_{324}.D_2 + \beta_{325}.D_3 + \beta_{326}.D_4 + \beta_{327}.CW2_S(-1) \end{aligned} \quad (4.5d)$$

Eastern Canada heifer carcass weight:

$$\begin{aligned} CW2_H = \alpha_{33} + \beta_{331}.PH2 + \beta_{332}.PF2 + \beta_{333}.T + \beta_{334}.D_2 \\ + \beta_{335}.D_3 + \beta_{336}.D_4 + \beta_{337}.CW2_H(-1) \end{aligned} \quad (4.5e)$$

Eastern Canada cow carcass weight:

$$CW\ 2_C = \alpha_{34} + \beta_{341}.PC2 + \beta_{342}.PF\ 2 + \beta_{343}.T + \beta_{344}.D_2 + \beta_{345}.D_3 + \beta_{346}.D_4 + \beta_{347}.CW\ 2_C(-1) \tag{4.5f}$$

U.S. steer carcass weight:

$$CW\,3_S = \alpha_{35} + \beta_{351}.PS\,3 + \beta_{352}.PF\,3 + \beta_{353}.T + \beta_{354}.D_2 + \beta_{355}.D_3 + \beta_{356}.D_4 + \beta_{357}.CW\,3_S(-1) \tag{4.5g}$$

U.S. heifer carcass weight:

$$CW\,3_H = \alpha_{36} + \beta_{361}.PH\,3 + \beta_{362}.PF\,3 + \beta_{363}.T + \beta_{364}.D_2 + \beta_{365}.D_3 + \beta_{366}.D_4 + \beta_{367}.CW\,3_H(-1) \tag{4.5h}$$

U.S. cow carcass weight:

$$CW\ 3_C = \alpha_{37} + \beta_{371}.PC\,3 + \beta_{372}.PF\ 3 + \beta_{373}.T + \beta_{374}.D_2 + \beta_{375}.D_3 + \beta_{376}.D_4 + \beta_{377}.CW\ 3_C(-1) \tag{4.5i}$$

where CW_{ij} is the carcass weight for i= 1, 2, 3 represents western and eastern Canada and the U.S. respectively, and j= S, H, C for steer, heifer and cow respectively.

4.3.3 Cattle Slaughter or Processor Conditional Demand Equations

The conditional demand for live cattle (steer, heifer and cow), labour and capital inputs are as shown below:

Western Canada cattle conditional demand equation:

$$\frac{\partial C^{WC}}{\partial PS1} = CS1 = \alpha_{81} + \left(\beta_{811} + \beta_{812}\left(\frac{WL12}{PS1}\right)^{1/2} + \beta_{813}\left(\frac{WK12}{PS1}\right)^{1/2}\right).\ QBS1 \tag{4.6}$$

Eastern Canada cattle conditional demand equation:

$$\frac{\partial C^{EC}}{\partial PS2} = CS2 = \alpha_{91} + \left(\beta_{911} + \beta_{912}\left(\frac{WL12}{PS2}\right)^{1/2} + \beta_{913}\left(\frac{WK12}{PS2}\right)^{1/2}\right).\ QBS2 \tag{4.7}$$

U.S cattle conditional demand equation:

$$\frac{\partial C^{US}}{\partial PS3} = CS3 = \alpha_{101} + \left(\beta_{1011} + \beta_{1012}\left(\frac{WL3}{PS3}\right)^{1/2} + \beta_{1013}\left(\frac{WK3}{PS3}\right)^{1/2}\right).\ QBS3 \tag{4.8}$$

Western Canada conditional demand for capital input:

$$\frac{\partial C^C}{\partial WK12} = DK12 = \alpha_{211} + \left(\beta_{2111} + \beta_{2112}\left(\frac{WL12}{WK12}\right)^{½} + \beta_{2113}\left(\frac{PS1}{WK12}\right)^{½} \right). \; QB1 \qquad (4.9)$$

Eastern Canada conditional demand for capital input:

$$\frac{\partial C^C}{\partial WK12} = DK12 = \alpha_{221} + \left(\beta_{2211} + \beta_{2112}\left(\frac{WL12}{WK12}\right)^{½} + \beta_{2213}\left(\frac{PS2}{WK12}\right)^{½} \right). \; QB2 \qquad (4.10a)$$

U.S. conditional demand for capital input:

$$\frac{\partial C^{US}}{\partial WK3} = DK3 = \alpha_{231} + \left(\beta_{2311} + \beta_{2312}\left(\frac{WL3}{WK3}\right)^{½} + \beta_{2313}\left(\frac{PS3}{WK3}\right)^{½} \right). \; QB3 \qquad (4.10b)$$

Western Canada conditional demand for labour input:

$$\frac{\partial C^C}{\partial WL1} = DL1 = \alpha_{241} + \left(\beta_{2411} + \beta_{2412}\left(\frac{WK12}{WL1}\right)^{½} + \beta_{2413}\left(\frac{PS1}{WL1}\right)^{½} \right). \; QB1 \qquad (4.11a)$$

Eastern Canada conditional demand for labour input:

$$\frac{\partial C^C}{\partial WL2} = DL2 = \alpha_{251} + \left(\beta_{2511} + \beta_{2512}\left(\frac{WK12}{WL2}\right)^{½} + \beta_{2513}\left(\frac{PS2}{WL2}\right)^{½} \right). \; QB2 \qquad (4.11b)$$

U.S. conditional demand for labour input:

$$\frac{\partial C^{US}}{\partial WL3} = DL3 = \alpha_{261} + \left(\beta_{2611} + \beta_{2612}\left(\frac{WK3}{WL3}\right)^{½} + \beta_{2613}\left(\frac{PUS}{WL3}\right)^{½} \right). \; QB3 \qquad (4.12)$$

where DLi and DKi = total quantity of ith input per ith region for i= 1, 2, 12, and 3 represents western and eastern Canada, Canada and the U.S. respectively. Other variables are as previously defined.

Trade restrictions effects as they affect the decision of firms are modelled in the conditional demand equations intercepts. The major trade dummy that is used in this study is the one that account for and the BSE trade restriction since May of 2003. The intercepts are modelled as:

$$\alpha_{i1} = \alpha_{i11} + \alpha_{i12}.D_5 \qquad i = 8,9,10,21,22,23,24,25,26.$$

D_5 is the dummy representing BSE with value of zero from the first quarter of 1980 to the first quarter of 2003 and one from the second quarter of 2003 to the fourth quarter of 2005.

To ensure the imposition of linear aggregation on the North American cost function, the price linkage equations were substituted into the input demand equations and the following restrictions were applied on the Western and Eastern Canada input demand equations:

$$\beta_{812} = \beta_{1012}$$

$$\therefore \beta_{812} = \beta_{1012} \cdot \left(\frac{WL3^{\frac{1}{2}} . PS3_i^{\frac{1}{2}}}{WL1^{\frac{1}{2}} . PS1_i^{\frac{1}{2}}} \right)$$

$$\beta_{813} = \beta_{1013}$$

$$\therefore \beta_{813} = \beta_{1013} \cdot \left(\frac{WK3^{\frac{1}{2}} . PS3_i^{\frac{1}{2}}}{WK12^{\frac{1}{2}} . PS1_i^{\frac{1}{2}}} \right)$$

$$\beta_{912} = \beta_{1012}$$

$$\therefore \beta_{912} = \beta_{1012} \cdot \left(\frac{WL3^{\frac{1}{2}} . PS3_i^{\frac{1}{2}}}{WL2^{\frac{1}{2}} . PS2_i^{\frac{1}{2}}} \right)$$

$$\beta_{913} = \beta_{1012}$$

$$\therefore \beta_{9123} = \beta_{1012} \cdot \left(\frac{WK3^{\frac{1}{2}} . PS3_i^{\frac{1}{2}}}{WK12^{\frac{1}{2}} . PS2_i^{\frac{1}{2}}} \right)$$

$$\beta_{2112} = \beta_{2312}$$

$$\therefore \beta_{2112} = \beta_{2312} \cdot \left(\frac{WL3^{\frac{1}{2}} . WK3^{\frac{1}{2}}}{WK12^{\frac{1}{2}} . WL1^{\frac{1}{2}}} \right)$$

$$\beta_{2113} = \beta_{2313}$$

$$\therefore \beta_{2113} = \beta_{2313} \cdot \left(\frac{PS3^{\frac{1}{2}} . WK3_i^{\frac{1}{2}}}{PS1^{\frac{1}{2}} . WK12^{\frac{1}{2}}} \right)$$

$$\beta_{2212} = \beta_{2312}$$

$$\therefore \beta_{2212} = \beta_{2312} \cdot \left(\frac{WL3^{\frac{1}{2}} . WK3^{\frac{1}{2}}}{WK12^{\frac{1}{2}} . WL2^{\frac{1}{2}}} \right)$$

$$\beta_{2213} = \beta_{2313}$$

$$\therefore \beta_{2213} = \beta_{2313} \cdot \left(\frac{PS3^{1/2}.WK3_i^{1/2}}{PS2^{1/2}.WK12^{1/2}} \right)$$

$$\beta_{2412} = \beta_{2612}$$

$$\therefore \beta_{2412} = \beta_{2612} \cdot \left(\frac{WK3^{1/2}.WL3^{1/2}}{WK12^{1/2}.WL1^{1/2}} \right)$$

$$\beta_{2413} = \beta_{2613}$$

$$\therefore \beta_{2413} = \beta_{2613} \cdot \left(\frac{PS3^{1/2}.WL3_i^{1/2}}{PS1^{1/2}.WL1^{1/2}} \right)$$

$$\beta_{2512} = \beta_{2612}$$

$$\therefore \beta_{2512} = \beta_{2612} \cdot \left(\frac{WK3^{1/2}.WL3^{1/2}}{WK12^{1/2}.WL2^{1/2}} \right)$$

$$\beta_{2513} = \beta_{2613}$$

$$\therefore \beta_{2513} = \beta_{2613} \cdot \left(\frac{PS3^{1/2}.WL3_i^{1/2}}{PS2^{1/2}.WL2^{1/2}} \right)$$

All variables are as defined in Appendix I.

Rearranging equation (3.11b) and incorporating the respective regional marginal costs from equations (3.7-3.9), we arrive at the following first order estimation equations:

For the Western region:

$$p_i = \sum_i \sum_j \beta_{8ij} .(w_i^{WC}.w_j^{WC})^{1/2} - \sum_{i=1} \sum_{i=1} \eta_i.\theta_i.p_i. + \sum_{i=1} \sum_{i=1} \varepsilon_i.\theta_{ii}.w_i..$$

$$\begin{aligned} \Rightarrow RPB1_i = {} & \beta_{811}.P1_i + \beta_{822}.WL1 + \beta_{833}.WK1 + 2.\beta_{812}.(WL1.P1_i)^{1/2} \\ & 2.\beta_{813}.(WK1.P1_i)^{1/2} + 2.\beta_{2112}.(WL1.WKc)^{1/2} - \\ & \sum_{i=1} \sum_{i=1} \eta_i.\theta_i.RPB1_i. + \sum_{i=1} \sum_{i=1} \varepsilon_i.\theta_{ii}.P1_i. \end{aligned} \qquad (4.13)$$

For the Eastern region:

$$p_i = \sum_i \sum_j \beta_{9ij} .(w_i^{EC}.w_j^{EC})^{1/2} - \sum_{i=1} \sum_{i=1} \eta_i.\theta_i.p_i. + \sum_{i=1} \sum_{i=1} \varepsilon_i.\theta_{ii}.w_i.$$

$$\Rightarrow RPB2_i = \beta_{911}.P2_i + \beta_{922}.WL2 + \beta_{933}.WK2 + 2.\beta_{912}.(WL2.P2_i)^{1/2} \qquad (4.14)$$
$$2.\beta_{913}.(WK2.P2_i)^{1/2} + 2.\beta_{2112}.(WL2.WKc)^{1/2} -$$
$$\sum_{i=1}\sum_{i=1}\eta_i.\theta_i.RPB2_i. + \sum_{i=1}\sum_{i=1}\varepsilon_i.\theta_{ii}.P2_i.$$

For the U.S.:

$$\Rightarrow RPB3_i = \beta_{1011}.P3_i + \beta_{1022}.WL3 + \beta_{1033}.WK3 + 2.\beta_{1012}.(WL3.P3_i)^{1/2} \qquad (4.15)$$
$$2.\beta_{1013}.(WK3.P3_i)^{1/2} + 2.\beta_{2212}.(WL3.WKus)^{1/2} -$$
$$\sum_{i=1}\sum_{i=1}\eta_i.\theta_i.RPB3_i. + \sum_{i=1}\sum_{i=1}\varepsilon_i.\theta_{ii}.P3_i.$$

where P_{ji} for j=1,2,3 represents western and eastern Canada and the U.S. respectively, and i= steer, heifer and cow. WL_K and WL_K WK_K and WK_K (K= 1, 2, 3) are labour wages and cost of capital, which are the prime business interest rate in the packing plants and retail stores for western and eastern Canada and U.S. respectively. θ_i *and* $.\theta_{ii}$ are the oligopoly (demand side) and oligopsony (supply side) coefficients of conjectural variation, and η_i ε_i are demand and supply elasticities for all the animal type in the regions.

The structural equations for the two conjectural elasticities for all regions are:

$$\theta_i^{WEST} = \alpha_{25} + \beta_{251}CU_{12} + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.FPS1 \qquad (4.16a)$$

$$\theta_{ii}^{WEST} = \alpha_{25} + \beta_{251}CU_{12} + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.WPS1 \qquad (4.16b)$$

$$\theta_i^{EAST} = \alpha_{25} + \beta_{251}CU_{12} + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.FPS2 \qquad (4.17a)$$

$$\theta_{ii}^{EAST} = \alpha_{25} + \beta_{251}CU_{12} + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.WPS2 \qquad (4.17b)$$

$$\theta_i^{US} = \alpha_{25} + \beta_{251}CU_3 + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.FPS3 \qquad (4.18a)$$

$$\theta_{ii}^{US} = \alpha_{25} + \beta_{251}CU_3 + \beta_{252}HFINDX + \beta_{253}T + \beta_{254}.D_5 + \beta_{255}.WPS3 \qquad (4.18b)$$

Due to the fact that tests for market power in beef marketing is carried out separately, the oligopoly and oligopsony coefficients of conjectural variation are not constrained to be identical. To identify the various parameters, the empirical estimation has to combine the information in equations (4.13-4.15) with the supply functions in equations (4.1a-4.3c) and the demand functions in equations (4.0a and b). Unlike Gohin and Guyomard (2000), this study specifies simple and separate linear demand and supply functions for the different cattle type and class before including the estimates into the simultaneous equation system to avoid estimation problems associated with multicollinearity. The full-information maximum likelihood estimator (FIML) is used to simultaneously estimate the equations due to its small sample properties following (Anders 2005)

Just like in equations 4.12-4.15, the processors' profit maximization equation for the North American market is developed to include the parameters for measuring both oligopoly and oligopsony power. Assuming the U.S. prices to be the dominant in this region as used in Cranfield (1995), the first order condition of the North American profit maximization equations can be expressed as:

$$RPB3 = \frac{MC^{NA}}{\left[\left(1 + \frac{\theta_i^{NA}}{\eta_{Q,P}^{NA}}\right) + \left(1 + \frac{\theta_{ii}^{NA}}{\varepsilon_{Q,w}^{NA}}\right)\right]} \tag{4.19}$$

This estimation will be done for North American cattle (steers, heifers and cows).

However, parametric estimation holds θ_i *and* θ_{ii} constant over the entire sample period. This overly restrictive assumption can be eliminated by defining a structural equation for θ_i *and* θ_{ii} and substituting this into equation (4.19). To allow θ_i *and* θ_{ii} change with economic conditions, Appelbaum (1982) specified θ as a function of the exogenous input prices. Lopez (1984) specified θ as a function of industry concentration and a time trend. Industry concentration was included to represent increased collusion as the number of firms reduces. Lopez (1984) also postulated that increased collusion increased market power. Time was included as a proxy for the effect of technological improvement on data and information processing capabilities. Schroeter (1988) followed

Appelbaum, but added time to account for omitted economic variables. However, Azzam and Pagoulatos (1990) specified θ as a structural parameter in the price rule. Also Azzedine and Pagoulatos (1999) contend that increasing throughput by increasing capacity utilization affects the nature of competition between firms. Haskel and Martin (1994) and Steindl (1952) showed that non binding capacity constraint leads to high concentration and a resultant oligopolistic firms that involve in price competition, thus driving price to equal marginal cost. Haskel and Martin (1994) also believe that as output expansion runs into capacity constraint, firms result into quantity competition otherwise, they are involved in price competition.

The North American marginal cost function market demand elasticity and market supply elasticity need to be explicitly specified and defined so as to complete the equations needed to achieve objectives one and two. The estimable North American marginal cost function drawn from equation 4.10 is presented as:

$$MC^{NA} = \beta_{1011}.PS3_i + \beta_{1022}.WL3 + \beta_{1033}.WK3 + 2.\beta_{1012}.(WL3.PS3_i)^{1/2} + \\ 2.\beta_{1013}.(WK3.PS3_i)^{1/2} + 2.\beta_{2212}.(WL3.WK3)^{1/2} \tag{4.20}$$

where MC is the marginal cost for North America, and other variables remain as earlier defined.

Following Cranfield's theorization of the North American market demand elasticity for beef, the retail prices and their derivatives for both Western and Eastern Canada and the U.S. were divided by the summation of the demand for beef in Canada and the U.S. This was done taking into consideration the retail price linkage so that prices across both countries are related. The North American retail market demand then becomes:

$$\eta^{NA}_{Q,P} = \begin{bmatrix} (\beta_{13}.\beta_{111}.ER).RPB12 \\ + (\beta_{33}.POP3).RPB3 \end{bmatrix} * \frac{1}{PCBD12 + PCBD3} \tag{4.21a}$$

Finally, North American material input supply equation for steer and heifer.

$$\varepsilon^{NA}_{Q,P} = \begin{bmatrix} (\beta_{411}.\beta_{131}.ER).PS1 + \\ (\beta_{421}.\beta_{161}.ER).PS2 + \\ (\beta_{61}).PS3 \end{bmatrix} * \frac{1}{SH1 + SH2 + SH3} \tag{4.21b}$$

The North American estimation uses equations 4.0a and b, 3.13, 4.6 through 4.8, 4.18a through 4.21 and 4.24 to simultaneously estimate the mode using the LSQ option. This is known to produce maximum likelihood estimates (Hall (1992) in Cranfield (1995)), which were further estimated using the FIML estimator. Spatial price relationship among factors of production used by beef processors is included through the price linkage equation 3.14a-3.15b and estimated with OLS, and substituted into the respective price variable in the Canadian slaughter cattle input equations 4.6 and 4.7. Equations 4.0a, 4.0b and 3.13, 4.1a-4.3c are estimated with OLS to obtain starting values that will be used in the simultaneous estimation. Equations were also estimated with OLS and substituted into the simultaneous estimation. The entire estimation process was carried out using the Time series processor (TSP) software version 5.0.

4.3.4 Cost economies and return to scale

Following Lopez et al (2002), a measure for the cost elasticity with respect to output is given by the ratio of industry marginal cost to average cost:

$$e_{cy} = \frac{A + 2HQB}{A + HQB},$$

where $A = \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2}$ and $B = \sum_i \beta_i w_i,$.

Morrison (2001b) also state that the characterization of market power depends on the cost structure, because it involves comparing the average cost of input or output to their marginal valuation. Hence constructed a cost economy measure similar to Lopez's in the form:

$$\varepsilon_{TCY} = \partial \ln TC / \partial \ln Y = \frac{m\arg inal\ \cos t}{change\ in\ output}$$. This reflects all internal cost economies. Where TC is the total cost of production and Y, the output. e_{cy} depicts economies of size and is the inverse of the degree of returns to scale. This study used the concept of equation 2.35 to estimate the cost economy measure.

Regional cost economy measure for cattle therefore have the form:

$$e_{cy} = \frac{A}{A + HB},$$

where $A = \sum_i \sum_j \alpha_{ij} w_i^{1/2} w_j^{1/2}$ and $B = \sum_i \beta_i w_i$, H is the Herfindahl index

Western Canada:

$$e_{cy} = \frac{\beta_{811}.PS1 + \beta_{822}.WL1 + \beta_{833}.WK12 + 2.\beta_{812}(WL1.\,PS1)^{1/2} + 2.\beta_{813}(WK12.PS1)^{1/2} + 2.\beta_{2212}(WL1.WK12)^{1/2}}{\beta_{811}.PS1 + \beta_{822}.WL1 + \beta_{833}.WK12 + 2.\beta_{812}(WL1.PS1)^{1/2} + 2.\beta_{813}(WK12.PS1)^{1/2} + 2.\beta_{2112}(WL1\,.WK12)^{1/2} + H1*(\beta_{811}.PS1 + \beta_{822}.WL1 + \beta_{833}.WK12)},$$

(4.22)

Eastern Canada:

$$e_{cy} = \frac{\beta_{911}.PS2 + \beta_{922}.WL2 + \beta_{933}.WK12 + 2.\beta_{912}(WL2.PS2)^{1/2} + 2.\beta_{913}(WK12.PS2)^{1/2} + 2.\beta_{2212}(WL2.WK12)^{1/2}}{\beta_{911}.PS2 + \beta_{922}.WL2 + \beta_{933}.WK12 + 2.\beta_{912}(WL2.PS2)^{1/2} + 2.\beta_{913}(WK12.PS2)^{1/2} + 2.\beta_{2112}(WL2.WK12)^{1/2} + H1*(\beta_{911}.PS2 + \beta_{922}.WL2 + \beta_{933}.WK12)},$$

(4.23)

The U.S:

$$e_{cy} = \frac{\beta_{1011}.PS3 + \beta_{1022}.WL3 + \beta_{1033}.WK3 + 2.\beta_{1012}(WL3.PS3)^{1/2} + 2.\beta_{1013}(WK3.PS3)^{1/2} + 2.\beta_{2212}(WL3.WK3)^{1/2}}{\beta_{1011}.PS3 + \beta_{1022}.WL3 + \beta_{1033}.WK3 + 2.\beta_{1012}(WL3.PS3)^{1/2} + 2.\beta_{1013}(WK3.PS3)^{1/2} + 2.\beta_{2212}(WL3.WK3)^{1/2} + H3*(\beta_{1011}.PS3 + \beta_{1022}.WL3 + \beta_{1033}.WK3)},$$

(4.24)

As observed in equations 4.22-4.24, If *B* is negative, then marginal cost is less than average cost and we have cost economies, which in our case is going to be scale economies (size increase). This is because the industry is observed in a long run framework. If *B* is positive, diseconomies of scale exist, and a rise in concentration raises prices through a rise in both oligopoly power and costs. When economies of scale are present *(B* < 0*)*, the effect of a rise in concentration on price can be positive, negative, or zero, depending on whether the oligopoly-power effect is larger than, smaller than, or the same as the cost-efficiency effect. A situation where B is not statistically different from zero means marginal cost equals average cost and we have constant returns to scale with firms making zero economic profits.

4.4 Summary

In this chapter the entire objectives of this thesis are addressed by specifying the required equations. An econometric model of market structure and market power for Western and Eastern Canada, and the United States is specified. A North American model was specified with price relationships, retail demand and cattle supply and supply response equations, and an oligopoly/oligopsony model. The results of these estimations are presented and discussed in the next chapter in line with the objectives of this thesis.

Also in the next chapter, the behavioural equations of the econometric model are combined with the market equilibrium and accounting identities to form the simulation model. The endogenous variables include retail beef price, per capita beef demand and total beef demand in Canada and the U.S. At the processing and farm sector level, the endogenous

variables are slaughter steer, heifer and cow prices, feeder calf price, steer heifer and cow and bull supply, the breeding herd inventory, carcass weights, live cattle demand and beef production. Endogenous trade variables linking the Canadian and U.S. markets include net exports of beef from western and eastern Canada to the U.S. and net exports of slaughter weight cattle from western Canada and eastern Canada to the U.S. The simulation is done over the entire sample period. The base simulation results are then compared with the corresponding actual values for model validation.

Chapter Five: ESTIMATION RESULTS

5.1 Background

In the previous chapter, a North American model allowing for market power was specified. In this chapter, the results of all the estimations identified in chapter four are presented and discussed as they relate to the purpose of this thesis. A simulation model is developed and used to validate the results of the entire model estimated, and two other separate simulations are run in order to estimate the volume and value of beef and cattle trade losses, and welfare benefits or losses that occurred as a result of the BSE crisis between 2003 and 2005. The entire results of beef demand, cattle supply, market power elasticity and cost economies are presented and discussed in this chapter.

5.2 Retail Beef Demand, Market Power, Costs Economy, and Supply Estimations

For the North American estimation, equations 4.0a and b, 3.13, 4.6 through 4.8, 4.18a through 4.21 and 4.24 were estimated simultaneously using the LSQ option. This is known to produce maximum likelihood estimates (Hall (1992) in Cranfield (1995)), which were further estimated using the FIML estimator. In order to impose spatial price relationship among factors of production used by beef processors, the price linkage equation 3.14a-3.15b were estimated with OLS, and further substituted into the respective price variable in the Canadian slaughter cattle input equations 4.6 and 4.7. Equations 4.0a, 4.0b and 3.13 were first estimated with OLS to obtain starting values that were used in the simultaneous estimation. Equations 4.1a-4.3c were also estimated with OLS and substituted into the simultaneous estimation. The entire estimation process was carried out using the Time series processor (TSP) software version 5.0.

For regional estimations, equations 4.13-4.15, 4.6 through 4.12, 4.16a through 4.17b, and 4.22 through 4.24 were estimated simultaneously. The coefficients on price for both demand and supply were obtained from the OLS estimation of equations 4.0a and b, and 4.1a-4.3c and were used in respective regional estimations. The full-information maximum likelihood estimator (FIML) is used to simultaneously estimate the equations due to its small sample properties following (Anders 2005) using TSP software version 5.0.

This part of the model estimation tried to achieve the objectives of this study by estimating the retail demand and input demand equations; measures of concentration, market structure and market power; and the presence or absence of cost economies in beef processing in western and eastern Canada, and in the U.S. Input demand are reported for cattle (steer, heifer and cow), capital and labour for each of the three regions and North America equations. Oligopoly/ Oligopsony power, Lerner index estimates and costs economies are also estimated for regional and North America equations.

The estimation results for Canadian and U.S. retail beef demand are shown in Table 5.1 and 5.2 for the period 1980-2005 and 1980-2003 using the LSQ estimator in multi-equation estimation. For the total sample period (1980-2005), the Durbin Watson (D-W) statistics showed that auto-correlation was not a problem in the model. In the U.S. equation, goodness of fit (81%) is higher than that of Canada (67%). Beef prices in Canada and the U.S. had a negative and significant relationship with beef demand, while the coefficients on chicken and pork in Canada and the U.S. were positive but only significant for chicken in Canada and pork in the U.S. Pork price had an insignificant relationship with beef demand in Canada. Thus, the relationship that existed between beef and pork and beef and chicken in the U.S. and Canada is that of substitutes.

A negative trend in consumption is evident in the time trend coefficient for both Canada and the U.S., and only significant in the U.S equation. The response of income to beef demand is positive and significant in the U.S. equation but negative and significant in the Canada equation. This means that consumers increase consumption as income increases in the U.S., while doing the reverse in Canada. Seasonality is also seen in the consumption patterns as captured by the seasonal dummies, where the second and third quarter consumption is positive and significant as compared to the first quarter in both equations. The fourth quarter seasonal variable, relative to the first quarter, beef consumption was negative and insignificant in Canada but positive and significant in the U.S. This is indicative of the fact that consumption is higher and significant during the summer months and lower in the winter period relative to the first quarter of the year.

Table 5.1 Regression Results for Retail Beef Demand (1980:1-2005:4) Using FIML

	Canada		U.S.	
Variables	Coefficients	T-statistics	Coefficients	T-statistics
Constant	12.634*	7.192	8.542*	16.892
Time	-0.005	0.395	-0.110*	-10.025
Income	-0.0003*	-3.311	0.001*	8.853
Beef price	-4.123*	-3.634	-12.055*	-6.479
Pork price	0.012	0.060	0.812**	1.842
Chicken price	1.239*	2.832	1.724	1.268
Q2	0.712*	4.636	0.293*	5.995
Q3	0.512*	3.353	0.491*	9.944
Q4	-0.145	-0.957	0.094*	1.961
D5	0.611*	2.336	0.039	0.354
Adjusted R^2	**0.67**		**0.81**	
D-W statistics	**1.92**		**2.01**	

***, **, *** significance at 99, 95 and 90 percent respectively.**

Table 5.2 show estimation results with a smaller sample size before the BSE crisis in 2003. Except for the fact that the income variable had a significant relationship with beef demand in Canada and the pork coefficient was positive, the statistical significance of variables remains the same as that of the total sample estimation. However, the magnitudes of the estimates in the sample before BSE are bigger than those of the entire sample estimation. This shows that beef disappearance were more responsive to meat prices before the BSE crisis of 2003 in both Canada and the U.S., which could be ascribed to health concerns as found in Lomeli (2005).

Table 5.2 Regression Results for Retail Beef Demand (1980:1-2003:1) Using LSQ

	Canada		U.S.	
Variables	Coefficients	T-statistics	Coefficients	T-statistics
Constant	13.7501*	7.8735	9.5716*	12.0697
Time	-6.10E-03	-0.5048	-0.1673*	-8.9159
Income	-2.00E-04*	-2.8326	0.0009*	4.4674
Beef price	-4.2568*	-4.4838	-23.4353*	-6.4705
Pork price	0.0674	0.3453	1.9906**	2.0870
Chicken price	0.7383***	1.7051	1.5732	0.8502
Q2	0.7243*	5.2499	0.3122*	8.1346
Q3	0.4405*	3.0649	0.4888*	11.0283
Q4	-0.1004	-0.7298	0.1052*	2.7346
Adjusted R^2	**0.79**		**0.90**	
D-W statistics	**1.98**		**2.04**	

***, **, *** significance at 99, 95 and 90 percent respectively.**

Table 5.3 contains the own price, cross price and income elasticities results with respect to quantity demanded. The own price elasticities for both Canada and U.S. have the expected signs and are inelastic in Canada as compared to the U.S., while cross price elasticities are within the range of previous studies with the expected signs except for pork in Canada for the total sample estimation. The cross price elasticities show more substitution relationships. They are however gross elasticities involving an income effect. The income elasticity for Canada reveals a declining response in beef demand to increasing income. This means that with an increase income, consumers' substitute beef for a different type of meat, probably chicken because it has high cross price elasticity for both sample periods. Income elasticity in the U.S. is positive and significant but higher in the period pre-BSE. In both equations, all elasicities are larger in the pre-BSE period than the total sample period estimates except in the cross elasticity for chicken.

Estimates of North America input demand and FOC presented in Table 5.4 show only capacity utilization and the BSE variable in the U.S. to be insignificant. Other variables are significant at the 99 percent statistical level.

The entire coefficient on the price and price interactions are positive. Positive prices satisfy concavity and monotinicity of the underlying cost function and indicate a significant effect of increasing factor costs on the mean price of beef. The BSE dummy (D5) has a negative sign in both in the Canadian equations and the conjectural elasticity equation. This shows that the effect of BSE has a negative impact on cattle slaughter in western and eastern Canada, and positive in the U.S, although insignificant. The response of inputs quantities to cattle price change as seen in Table 5.5 is significant for all inputs and carries the expected signs.

Estimates of market structure, oligopoly-oligopsony conduct as expressed by the market power coefficients and cost economies are shown in Table 5.8. All variables are estimated at their mean and a detailed result of quarterly estimates is provided graphically in appendix II-VI.

Table 5.3 Retail Demand Elasticites for Beef In Canada and the U.S.

Quantity demanded	Beef	Chicken	Pork	Income
Canada 1980:1-2003:1	-0.401*	0.236***	0.036	-0.392**
U.S. 1980:1-2003:1	-0.596*	0.045	0.132**	0.535*
Canada 1980:1-2005:4	-0.387*	0.408*	0.004	-0.545*
U.S. 1980:1-2005:4	-0.309*	0.048	0.054**	0.852*
North America	-0.147			
Previous Estimates (Canada)				
Trypo and Tryphonopoulus (1973)	-0.521			
Hassan and katz(1975)	-0.767			
Hassan and Johnson(1979)	-0.453			
Curtin et al (1987)	-0.373	0.166	-0.070	0.167
Young(1987)	-0.480			
Coleman and Meilke(1990)	-0.47	0.05		1.03
Goddard and Chyc(1990)	-0.445	0.093	-0.015	0.711
Alston and Chalfant (1991)	-0.660			
Chalfant, Grey and white(1991)	-0.403			
Chen and veeman(1991)	-0.770	0.12	0.21	0.93
Reynolds and Goddard (1991)	-1.0482	-0.102	-0.115	1.2652
Reynolds and Goddard (1991)	-0.736	-0.102	-0.115	1.2652
Goddard and Cozzarin(1992)	-1.080	-0.264	-0.135	1.14
Moschini and Vissa(1993)	-0.837			
Cranfield (1995)	-0.556	-0.307	-0.0666	1.448
Eales(1996)	-0.810			
Xu and Veeman(1996)	-0.797			
Goddard et al (2004)	-0.455			
Lomeli (2005)	-0.428	-0.363	-0.463	
Previous Estimates (US)				
Chavas (1983)	-0.967	0.176	0.064	
Moschini and meilke (1984)	-0.89	0.05		
Wohlgenant (1985)	-1.14	0.15	-0.09	
Eales and Unneveher (1988)	-0.57	0.171	0.052	
Moschini and Meilke(1989)	-0.983	-0.004	-0.124	
	-1.05	-0.078	-0.129	
Jensen and Schroeter(1992)	-1.25	0.886	0.215	
Brester and Schroeder(1994)	-0.49	0.19	0.01	
Moschini and Vissa(1993)	-0.837			
Goddard and Griffith(1992)	-0.47	-0.46	-0.12 1	-0.79

* , **, *** significance at 99, 95 and 90 percent respectively.

Table 5.4 NA Input Demand Equation and Conjectural Elasticity Estimates

Variables	Western Canada	Eastern Canada	U.S./North America	FOC U.S./ NA
Constant	62624*	25442*	0.0098*	
D5 (BSE)	-0.0003*	-0.001*	0.0004	
WP				0.002*
WK				0.001*
WL				0.001*
WLP				0.0007*
WKP				0.0002*
WLK				0.0356*
Θ Constant				-0.1513*
Time				0.0002***
Herf.Index				0.1679*
Cap. Util.				-0.0681
D5				-0.0102*
Farm price				-0.0956*
Wsale price				0.0942*
D-W	2.54	1.92	2.26	0.215
R^2				0.58

*, **, *** significance at 99, 95 and 90 percent respectively.

Table 5.5 Input Demand Elasticities (1980-2005)

Quantity Demanded	*North America*
	Cattle price
Cattle	-0.0302*
Capital	0.0112*
Labor	0.0291

P

Table 5.6 shows the processor's input demand and first order condition estimation results for the regional models. All estimated equations were corrected for auto-correlation and their adjustment parameters were significant. The BSE variable (D_5) in the intercept term had a negative coefficient for both eastern Canada and the U.S., and positive for western. Packer demand for live cattle, capital and labour were positive except for cattle and capital in the U.S. that had a negative sign. Cross price interactions show capital-price coefficient to be negative for all regions while, labour-capital and labour-price are positive for all regions with the exception of eastern Canada where they happen to carry negative signs. This generally shows that increase in cattle, labour and capital prices have marginal positive effects on inputs demanded by processors. The input demand equations were devoid of auto-correlation. The negativity of some inputs in some regions violates the condition of monotonicity of the underlying cost function, but concavity is been satisfied since none of the price interaction coefficients are less than zero.

Results of the first order condition (FOC) oligopoly/oligopsony coefficients were significant for Canadian equations. The U.S. had the time, BSE, and wholesale price variables significant at 95 and 99 percents. Time affects both conjectures positively except in eastern Canada, and the BSE dummy negatively affects both conjectures in western Canada, and positive for the other regions. This is because the BSE negative impact is more in western Canada than in the other regions. Capacity utilization is seen to increase conjectural elaticities in western Canada and the U.S. but reduces conjectural elasticities in the east due to less number of concentrated firms in the east.

Time affects both conjectures positively except in eastern Canada, and the BSE dummy negatively affects both conjectures in western Canada, and positive for the other regions. This is because the BSE negative impact is more in western Canada than in the other regions. Capacity utilization is seen to increase conjectural elaticities in western Canada and the U.S. but reduces conjectural elasticities in the east due to less number of concentrated firms in the east.

Table 5.6 Regional Input Demand Equation and Conjectural Elasticity Estimates

Variables	Western Canada	Eastern Canada	U.S./North America	FOC West	FOC East	FOC U.S./ NA
CONSTANT	453.079*	435.29*	726.445			
D5 (BSE)	4.61E-08	-1.54E-07	-3.20E-10			
WP	0.013076*	0.043487	-0.0454			
WL	4.94E-08	1.04E-06	3.08E-05*			
WK	3.09E-06	8.83E-07	-2.81E-08			
WLP	-9.15E-06**	1.93E-06	1.62E-07			
WKP	-3.48E-06	-2.77E-05	-2.03E-07*			
WLK	-6.90E-08	1.73E-07	2.07E-09*			
Θ Constant				-0.1898*	0.1050*	0.0022
Time				0.0009*	-0.0005*	0.00002**
Herf.Index				0.0987*	-0.0401**	-0.0041
Cap. Util.				0.0845**	-0.0525*	0.0026
D5				-0.0098*	0.0044*	0.0009*
Farm price				-0.5224	-1.0061	4.4803*
Wsale price				-0.2413*	0.1599*	0.0634*
D-W	2.33	2.01	2.26	1.17	1.17	1.27
R^2				0.86	0.85	0.96

*, **, *** significance at 99, 95 and 90 percent respectively.

Increase farm and wholesale prices decreases the conjectural elasticities in western Canada and increases in the U.S. However, only farm price had a negative effect in eastern Canada. The Herfindahl index lowers the conjectural elasticities in the U.S. equation and in eastern Canada, but increases the conjectural elasticities in western Canada. All equations had a high goodness of fit values. Inputs elasticity results are presented in Table 5.7 for all the regions. The results had the appropriate signs for most of the estimations.

Table 5.7 Input Demand Elasticities (1980-2005)

Quantity Demanded	*Western Canada*			*Eastern Canada*			*United States.*		
	Cattle	*Capital*	*Labor*	*Cattle*	*Capital*	*Labor*	*Cattle*	*Capital*	*Labor*
Cattle	-0.002	0.21	0.02	-0.013	-0.72	0.49	-0.006	-2.58	-0.03
Capital	0.002	-0.21	0.46	0.013	0.72	-0.014	0.0006	2.58	-1.07
Labour	0.0001	0.005	-0.47	2.0E-05	-0.005	-0.49	-0.0002	-0.046	1.11

The market on the supply side to retailers as indicated by the conjectural elasticities is oligopolistic in magnitude, but only statistically significant in North America. On the supply side, both the regional and North American estimations had statistically significant mean monopsony price distortion estimates of less than 20 percent. Therefore the market is not perfectly competitive since it exerts some significant degree of mark-down in cattle prices. The North American oligopoly power estimate (0.149) found in this study is in line with the findings of Cranfield (1985), who also found significant oligopolistic market power in North America of 0.309.

It means that on the beef supply side for cattle, a one percent increase in an average firms' output would raise the industry output by 22 percent in western Canada, 27.8 percent in eastern Canada, 53.3 percent in the U.S., and 14.9 percent in North America. On the other side of cattle demand, an industry output is expected to significantly rise by 20.3, 12.4, 1.0 and 16.9 for every one percent rise in an average firm's output in western Canada, eastern Canada, the U.S. and North America, respectively. The estimations from retail demand analysis to supply response and the market structure estimates so far address objective number one of this thesis

The Lerner indices show the degree of market power (monopoly-monopsony) exertion and their percentage mark-ups and mark-downs of beef prices and cattle prices as compare to the case in a perfectly competitive market. Reading from the estimates on average from the beef supply side, beef processing firms in western Canada have been able to affect price above marginal cost by about 4.8 percent in western Canada, 6.1 percent in eastern Canada, 21.9 percent in the U.S, and 16.9 percent in North America.

However, these estimates are not significantly different from zero in all regional estimates with the exception of North America estimation, which had significant oligopolistic market power. Demand side estimates show significant processors' price effect over marginal cost of 0.4, 0.2, 0.02 and 6.0 percents in western and eastern Canada, the U.S. and North America respectively. The Lerner indexes further supports the result that though the industry has not been perfectly competitive; it does exert significant oligopoly power. The oligopsony estimates have limited magnitude in terms of mark-down in cattle prices.

Table 5.8 Conjectural Elasticities, Lerner Indices and Cost Economy Measures

Elasticities and other estimates	Western Canada	Eastern Canada	United States	North America
Θ for Oligopoly	0.2203	0.2778	0.5332	0.1499*
Θ for Oligopsony	0.2028*	0.1242*	0.0176***	0.0399*
LI for Oligopoly	0.0484	0.0609	0.2195	0.1691*
LI for Oligopsony	0.0041*	0.0016*	0.0002*	0.0618*
Cost Economies	0.928*	0.927*	0.864*	0.8641*
B	0.0345**	0.0139	-0.0251	0.0747*

Note: Null hypothesis of $e_{cy} = 1$, which represents constant return to scale (CRS).

In Table 5.8., the average cost elasticity with respect to output, which measures economies of size, indicates that all regional firms and North America composite firms have significant diseconomies of size and estimates that are close to those of (CRS). These estimates are consistent with previous findings in the U.S. in the meat packing industry. Average estimates from Lopez et al (2002), Morrison Paul (2000) and Bhuyan Lopez (1997) were 0.997, 0.965 and 0.834, respectively. None of the regions exhibit a constant return to scale on investment, where marginal cost would be equal to average cost and at which point zero profit is obtained. The fact that the sign of the hypothesis for the presence of economies/diseconomies of scale (B) coefficient is positive tells us that marginal cost is greater than average cost hence, diseconomies of scale. This means that a rise in concentration affects prices through a rise in both oligopoly-oligopsony power and costs. The implication is that increasing costs have a benign effect on oligopolistic-oligopsony power of processing firms, and that prices are a function of both market power and increasing cost of production since the firms do not enjoy economies of scale. This confirms the previous finding of lack of significant oligopoly power and minimal oligopsony power in the industry due to amplified costs.

However, the negative but insignificant sign on the cost economy coefficient for the U.S. is an indication that average cost is greater than marginal cost; hence there are economies of scale in production. The results from the Lerner index and cost economies answer the question to objective number two.

Table 5.9 shows the results from the price linkage equations. In all equations, the effect of time, U.S. price, net trade and lagged dependent variable are significant between 95% and 99% levels except for labour in eastern Canada equations. Time has a negative relationship and all other variables are positively related with the exception of net trade on the price of cows and bulls in eastern Canada, and the price of beef in Canada, which has a negative response. The eight different equations seemed to fit the data properly as evident in their high adjusted R-squared values and Durbin-h statistics, which show less autocorrelation.

Table 5.9 Canada - U.S. Price Linkage Equations Regression Results Using OLS Estimator (1980:2-2005:4)

Dependent Variables	**Independent variables Coefficients**						
	Constant	*Time*	*U.S. Price*	*Net Trade*	*LDV*	*R^2adj.*	*D-h stat*
RPB12	0.1808*	-0.0003**	0.3051*	-1.82E-10**	0.5509*	0.90	-1.20
PSH1	0.0137	-0.0004*	0.4519*	9.97E-08*	0.3567*	0.93	2.36
PSH2	0.0557**	-0.0005*	0.3149*	2.39E-07**	0.4810*	0.94	2.34
PCB1	0.1907**	-0.0148*	0.0561	1.91E-05**		0.90	1.22
PCB2	0.0923**	-0.0089*	0.0600**	-4.73E-05**	0.3500*	0.95	2.05
WL1	2.7509*	-0.0054**	0.1775*		0.6541*	0.92	-2.39
WL2	2.5873**	-0.0061**	0.0158		0.8769*	0.91	-0.53
WK12	0.6071	-0.0104**	0.2998*		0.5974*	0.98	5.44

* and ** significance at 99 and 95 percent respectively.

Price transmission elasticities (Table 5.10) show that the corresponding increase in Canadian prices from a one percent increase in U.S. prices is small. It means that price transmission across the border is not perfect as indicated by the data, since the Canadian prices response is far below fifty percent in virtually all U.S. price increase. Price of steer and heifer in western Canada had the highest response of 64 percent transmission. Price transmissions are much smaller for steer and heifer and labour, and bigger for cow and bull between eastern Canada and the U.S. relative to those of western Canada and U.S.

This could be attributed to the relatively larger size of the U.S. economy, which enjoys economy of size and scale. Transportation and other marketing costs could also be responsible for this incomplete price transmission. Previous research estimates that are presented alongside to compare with this study's are larger than the estimates obtained from this study.

Table 5.10 Canada-U.S. Price Transmission Elasticities (1980-2005)

Equations	Elasticities
Canada/US retail price of beef	0.257
Western Canada/US steer & heifer price	0.640
Easter Canada/US steer & heifer price	0.426
Western Canada/US cow and bull price	0.143
Eastern Canada/US cow and bull price	0.144
Western Canada/US labour rate	0.189
Eastern Canada/US labour rate	-0.016
Canada/US interest rate	0.419
CRANFIELD (1995)	
Retail price	1.002
Western Canada-U.S farm price	0.931
Eastern Canada-U.S. farm price	0.914
Canada – U.S. labour rate	0.284
Canada – U.S. interest rate	0.529
Coleman and Meilke(1988)	
Western Canada-US steer price	0.77
Eastern Canada-US steer price	0.75

Feeder cattle price linkage shows the relationship between the fed cattle market, breeding herd and the number of cattle available for placement on feed and/or slaughter. Table 5.11 shows the results of this relationship with a good fit of the model, and all variables in all equations having the appropriate signs. The time variable was removed from the western and eastern Canadian equation for easy estimation as it wasn't significant and seems to reduce the significance of the joint estimation. The seasonal dummies are not significant in western and eastern Canada except for the third quarter relative to the first quarter in eastern Canada. All other variables in eastern and western Canada are significant at 95 and 99 percent. With the exception of the intercept coefficient, all variables have significant coefficients in the U.S.

Feeder price linkage elasticities with respect to steer price and feed price are shown in Table 5.12. Increases in feed prices reduce fed cattle available for market or cattle availability to be placed on feed or slaughter. Feeder cattle have an elastic response to increase in steer prices and share a positive relationship with the U.S. having the least response.

Table 5.11 Feeder Cattle Price Linkage Regression Results (OLS) 1980:1-2005:4.

Variables	**Western Canada**		**Eastern Canada**		**United States**	
	Coefficient	T-Stat	Coefficient	T-Stat	Coefficients	T-Stat
Constant	0.030**	2.631	0.026*	2.826	0.004	0.683
Steer price	0.353*	5.773	0.427*	6.837	0.346*	6.588
Feed price	-0.708*	-6.266	-0.472*	-5.491	-0.409*	-4.700
LDV	0.723*	16.697	0.585*	10.657	0.615*	12.714
Q2	0.002	0.444	0.011**	2.336	-0.003**	-2.571
Q3	0.004	0.808	0.002	0.372	-0.005*	-3.722
Q4	-0.00006	-0.011	0.010**	2.110	-0.007*	-5.006
Time					0.00007**	1.957
D-h stat.	1.08		0.35		1.50	
R^2adj	0.89		0.91		0.92	

*, **, *** significance at 99, 95 and 90 percent respectively.

Table 5.12 Feeder Cattle Price Elasticities (1980-2005)

	Western Canada	**Eastern Canada**	**United States**
Steer price	0.325	0.544	0.101
Feed price	-0.726	-0.105	-0.104

Table 5.13 contains regression results for cow and bull supply. The U.S equation had a better fit than the Canadian equations and all equations with the exception of western Canada show no sign of auto-correlation as indicated by the Durbin h-statistics. The price used in the U.S. equation is the ratio of feeder to cow price in the U.S. Except for the coefficients for second and fourth quarter seasonal variables in eastern Canada and fourth quarter in western Canada, all other variables were significant. Feeder prices exhibit a negative relationship with the breeding herd supply in all equations. This means that as an investment or capital good, increasing feeder prices, decrease the supply of cow and bulls because of enhanced expectations of their profitability. Cow and bull supply

had a negative and significant relationship with animals for slaughter in both Canada U.S. equations. The BSE dummy variable is significant and positive in the U.S, positive in eastern Canada and significant with a negative relationship in western Canada. This shows that the effect of BSE had a negative impact on cow and bull supply in the west where most of the fed cattle are found and where the disease is predominantly having outbreaks.

Inventories are positively related to cow and bull supply in the U.S. equation as inventories increase, supply of the animal for slaughter would have to increase so as to give room for fresh stock or to reduce stock capacity to a manageable number. The negative sign of western and eastern Canada's inventory coefficient could also be due to increased expectation in the profitability of the breeding herd. The seasonal dummies show variation in cow and bull supply at different season relative to the first quarter of the year.

Table 5.13 Cow and bull supply regression results (1980:1-2005:4)

Variables	**Western Canada**		**Eastern Canada**		**United States**	
	Coefficients	T-Values	Coefficients	T-Values	Coefficients	T-Values
Constant	158809*	9.205	223060*	3.021	356347	1.124
Feeder Price	-101436**	-2.003	-147619*	-2.969	-4.68111*	-4.297
Inventories			-0.0679	-1.429	0.11022**	1.732
Time			-679.04*	-5.026	1476.18**	2.393
Q2	-20178.1*	-2.598	2466.22	0.534	63945.1**	2.275
Q3	-25796.1*	-3.320	-9070.52*	-1.971	179850*	5.994
Q4	12504.1	1.609	7414.24	1.537	320631*	11.062
D5	-27663.6*	-3.232	4172.23	0.716	-78924.9**	-2.259
LDV			0.2550*	2.610	0.691*	11.648
D-W stat.	1.27					
Durbin-h Stat.			-3.29		-0.409	
R^2adj	0.37		0.56		0.82	

*, **, *** significance at 99, 95 and 90 percent respectively.

Elasticity results are presented in Table 5.14 and are all within range and signs of those found in previous studies except in the signs of inventory in eastern Canada.

Table 5.14 Cow and Bull Supply Elasticities (1980-2005)

Cattle supply	Western Canada	Eastern Canada	United States
Feeder price	-0.291	-0.523	-0.326
Inventories		-0.978	0.283
Previous studies			
Martin and Haack (1977)			
Feeder price	-0.42	-0.02	-0.21
Goddard (1979)			
Feeder price	-0.6	-0.08	-0.33
Inventory	0.37	1.28	1.30
Coleman & Meilke (1988)			
Feeder	-0.26	-0.16	-0.23
Cousineau (1993)			
Feeder price	-0.18	-0.19	-0.22
Cranfield (1995)			
Feeder price	-0.33	-0.272	-0.313
inventories	1.834	0.136	2.197

All parameter estimates in Table 5.15 are significant except for the third and fourth seasonal dummy variable in eastern Canada and the fourth seasonal variable in western Canada. Supply response to price is positive as expected, with the exception of inventory in eastern Canada. Time was not included in the U.S. equation because it reduced the significance of the entire equation. All equations had a good fit however auto-correlation was detected in eastern and western Canada equation. After correcting for it, the adjustment parameter was small and insignificant, hence this specification is maintained. The BSE dummy had a negative and significant relationship with steer and heifer supply in western Canada as expected, where the disease is predominant and the region with the largest concentration of fed cattle in North America. Eastern Canada supply had a positive impact from BSE as seen in the positive and significant coefficient for BSE dummy. The BSE dummy was not used in the U.S. equation because it reduces the significance of other explanatory variables and the significance of the entire model prediction.

Table 5.16 show the response of steer and heifer price and inventories on regional cattle supply. Estimates have signs according to a priori expectations. Supply is more elastic to price in the U.S. than in Canada. Other estimates agree with elasticities from previous studies.

Table 5.15 Steer and Heifer Supply Regression Results (OLS). (1980:1 2005:4)

Variables	**Western Canada**		**Eastern Canada**		**United States**	
	Coefficients	T-Values	Coefficients	T-Values	Coefficients	T-Values
Constant	-80590.1	-0.906	266522*	5.766	2.54E+06*	3.722
Price	358393***	1.741	208919*	3.016	3.28E+06**	2.301
Inventories	0.0994*	3.075	-0.1908*	-4.184	0.0293**	1.980
Time	2568.06*	3.214	-208.688	-1.324		
Q2	62241.3*	4.011	11296.3**	2.035	431028*	6.447
Q3	65539.6*	4.243	6230.76	1.128	292171*	3.778
Q4	22231.6	1.427	6671.09	1.217	-295856*	-3.641
D5	-87814.6*	-3.953	36540*	5.139		
LDV					0.5156*	5.638
Durbin-h					-1.67	
D-W stat.	1.32		0.76			
R^2adj	0.80		0.63		0.64	

*, **, *** significance at 99, 95 and 90 percent respectively.

Breeding herd inventory regression results are shown in Table 5.17 with all regional equations having a high goodness of fit and Durbin-h statistics that show no auto-correlation except in the U.S. equation. The coefficients on lagged dependent variable, interest rate and all seasonal dummies were significant for western Canada, and lagged dependent variable for eastern Canada. The signs on coefficient for western and eastern Canada were as expected. All the variables in the U.S. equation except the constant term were all significant and had the appropriate signs. The negative sign on interest rate shows that an increase in discount rate reduces inventories as farmers' value immediate returns. The positive signs on feeder price estimate show that farmers increase breeding inventories with increase in feeder prices for profitability, so that calves population could increase in order to increase feeder replacement.

The inventory elasticity results are shown in Table 5.18. They agree with previous studies but are smaller in magnitude or values. This could possibly be due to the scaling of the variable during estimation.

Table 5.16 Steer and Heifer Supply Elasticities (1980-2005)

Cattle supply	Western Canada	Eastern Canada	United States	North America
Price	0.2062	0.3204	0.0561	0.369
Inventories	0.6731	-0.7082	0.1577	
Previous studies				
Reutlinger (1966)				
Steer equation			0.162	
Heifer equation			-0.631	
Kulshreshtha (1976)				
Steer price	0.241	0.090		
Martin and Haack (1977)				
Steer price	-0.09	0.08	0.12	
Goddard (1979)				
Steer price	0.28	-0.20	0.07	
Inventory	0.52	0.60	0.73	
Coleman & Meilke (1988)				
Steer price	-0.44		-0.15	
Cousineau (1993)				
Heifer equation price	-0.32	-0.06	-0.27	
Steer equation price	-0.48	-0.56	-0.23	
Cranfield (1995)				
Steer price	0.431	0.191	0.006	
Inventories	0.182	0.294	0.339	
Aadland and Bailey(2001)				
Steer & heifer price			-3.59	

Table 5.17 Regression Results for Beef Cow and Bull Inventory using OLS (1980-2005)

Variables	Western Canada	Eastern Canada	United States
Constant	33157.5	453.654	-1.17E+06
Feeder price	160430***	119.864*	9.21E+06*
WK	-3400.58**	-243.129	-102754*
LDV	0.8262*	0.9855*	1.0220*
Q2	-70465.8*	-3974.43*	-30171.9
Q3	-70693.6*	-4309.31*	-662089*
Q4	-71083.3*	-3817.41	-635814*
Dh-statistics	-0.91	0.03	5.99
R^2 adjusted	0.99	0.96	0.98

*, **, *** significance at 99, 95 and 90 percent respectively.

Table 5.18 Beef Cow and Bull Inventory Elasticities

Cattle supply	Western Canada	Eastern Canada	United States
Feeder cattle price	0.0139	0.0090	0.0218
Interest rate	-0.0065	-0.0020	-0.0066
Previous studies			
Tryfos (1974)			
Feeder	0.004		
Freebairn & Rausser (1975)			
Feeder price			0.2
Martin and Haack (1977)			
Feeder price	0.2	0.31	0.12
Goddard (1977)			
Feeder price	0.21	0.29	0.11
Interest rate	-0.08		
Coleman and Meilke (1988)			
Feeder price	0.09	-0.01	0.09
Cousineau (1993)			
Feeder price	0.12	0.09	0.11
Cranfield (1995)			
Feeder price	0.108	0.141	0.128
Interest rate	-0.089		

The estimation result of carcass weights as endogenous variables is presented in Table 5.19. Except for steer and heifer prices in western and eastern Canada; feed price for heifer and cow in both western and eastern Canada, and steer and heifer in the U.S.; all other variables are significant at 90 or 95 percent. Durbin-h statistics show little problem of auto-correlation in all equations, and the equations had a good fit with the data with very high adjusted R-square values. The results also show that different seasons have different effects on carcass weight of different cattle types. Elasticity results are shown in Table 5.20 for cattle and feed prices.

Table 5.19 Regression Estimates for Carcass Weight AR1 Equations (1980-2005)

Variables	**Western Region**			**Eastern Region**			**United States**		
	steer	**heifer**	**cow**	**steer**	**heifer**	**cow**	**steer**	**heifer**	**cow**
Constant	143.8*	99.2*	90.80*	95.84*	86.82*	41.5**	129.8*	112.0*	37.60*
Price	3.27	1.52	66.9**	12.42	4.38	83.9**	70.6**	100.5*	70.5**
Feed price	67.4**	30.26	32.50	90.2**	28.47	50.69	47.55	-24.23	-98.4**
Time	0.52*	0.58*	0.47*	0.44*	0.38*	0.31*	0.18*	0.18*	0.09**
Q2	-7.37*	-11.7*	-14.83*	-7.97*	-8.41*	-4.38	-1.32	-3.31*	-9.72*
Q3	8.18*	3.72	-11.99*	-3.7***	-5.30*	-2.97	10.24*	6.03*	-9.84*
Q4	4.19**	0.67	-17.19*	2.73	1.10	1.60	7.79*	6.21*	-8.98*
LDV	0.47*	0.57*	0.59*	0.62*	0.64*	0.71*	0.60*	0.63*	0.84*
D-h	**2.76**	**0.88**	**-0.32**	**3.84**	**4.31**	**-1.94**	**0.88**	**1.30**	**0.39**
R^2 adj	**0.95**	**0.97**	**0.9**	**0.95**	**0.96**	**0.71**	**0.95**	**0.97**	**0.97**

* , **, *** significance at 99, 95 and 90 percent respectively.

Table 5.20 Carcass Weight Elasticities (1980-2005)

Cattle supply	**Western Canada**	**Eastern Canada**	**United States**
Steer price	0.0028	0.0039	-0.0258
Heifer price	-0.0015	0.0126	-0.0367
Cow price	0.0463	0.062	0.0257
Feed price steer	0.0137	0.022	0.0034
Feed price heifer	0.007	0.008	-0.0019
Feed price cow	0.00746	0.0155	-0.0099

Table 5.21 show results of regional price of steers' regression for the entire sample period. The price of steer and heifer (PSH) and the lagged dependent variable are all significant and positive according to a priori expectations. The estimation had a high goodness of fit with the data; however auto-correlation happens to be present in two of the three estimates. This estimation is done in order to endogenize price of steer to be used in the simulation model later on in this study. Likewise the results for price of cow and bulls estimated for simulation purposes in Table 5.22. The variables are significant with the expected signs.

Table 5.21 Regression estimates for Price of Steers (1980-2005) Using OLS Estimator.

Variables	**Western Canada**		**Eastern Canada**		**United States**	
	Coefficient	T-values	Coefficient	T-values	Coefficient	T-values
Constant	-0.0029	-0.943	0.007	1.134	-0.0062	-13.388
PSH	0.9743	33.441	0.972	105.433	1.0721	86.090
LDV	0.032037	1.158	3.2E-06	0.057	0.0302	2.788
Q2	0.0012	0.791	0.0028	1.695	0.0003	1.103
Q3	-0.0017	-1.071	0.0001	0.080	0.0006	2.408
Q4	-0.0007	-0.467	0.0003	0.211	0.0004	1.493
Dh-statistics	1.809		1.57		8.35	
R^2 adjusted	0.99		0.99		0.99	

Table 5.22 Regression estimates for Price of Cow and Bull (1980-2005) using OLS Estimator.

Variables	**United States**	
	Coefficient	T-values
Constant	-4.70E-03	-3.829
PSH	0.776159	25.417
LDV	0.051605	1.449
Q2	1.46E-04	0.222
Q3	-2.76E-03	-3.992
Q4	-4.07E-03	-6.412
Durbin-h stat.	8.401	
R^2 adjusted	0.98	

The earlier part of this chapter has concentrated on the results of the entire model specified in chapter four. Breeding herd inventory equations were estimated to explain the cow-calf sector of the industry and how they link to the feedlot operations through the feeder cattle price linkage equation estimations. Cow and bull supply and steer and heifer supply represent the feedlot sector in the modelling process and are affected by steer and heifer prices, feed prices and cattle inventories. Carcass weight and price linkage equations were estimated to help in explaining price transmission across the border between Canada and the U.S. Processors profit maximization and pricing conditions are modelled in their input demand equations, and conjectural elasticities are estimated simultaneously in order to determine market competitiveness in terms of cattle demand from farmer and beef supply to retailers. The entire model structure therefore captures the whole beef cattle sector's decision making and pricing dynamics. The remaining sections of this chapter contain simulation results for the validation of the estimated model and for measuring the impact of BSE in terms of consumer and producer surpluses, and processors' profit margin.

5.3 Simulation Results

One advantage of using time series data is the ability to simulate the results by applying some shocks to variables and seeing how they affect the entire system being modelled. Most important is the use of simulation to validate a model and show how adequate and close the model approximates or fits the actual data used in estimation. The following validation statistics are used to assess the goodness of the estimated model and are conditional on the model's restrictions, assumptions and hypotheses. Quarterly data over the period 1980:1 to 2005:5 is used for the simulations, and validation statistics and graphical comparisons are presented for all endogenous variables in the model estimated in chapter four. A dynamic type of simulation is used in this study to arrive at these validation statistics.

5.3.1 Correlation Coefficient Between Actual and Predicted Values

This statistics show how the predicted or estimated values and the actual values from the data move together, i.e., how correlated they are. The correlation coefficient is calculated using the formula: (Judge, 1985)

$$\rho = \frac{\frac{1}{n}\cdot\sum_{t}^{n}\left(p_t - \bar{p}\right)\cdot\left(a_t - \bar{a}\right)}{\left(\frac{\sum_{t}^{n}\left(p_t - \bar{p}\right)^2}{n}\right)^{1/2}\cdot\left(\frac{\sum_{t}^{n}\left(a_t - \bar{a}\right)^2}{n}\right)^{1/2}} \qquad (5.1)$$

where ρ = correlation coefficient,

p_t = simulated value,

a_t = actual value, and

n = number of observations.

The predicted values are either positively or negatively correlated with the actual values based on the values of ρ, which ranges from -1 to 1. Perfect negative correlation is achieved at $\rho = -1$, and perfect positive correlation is achieved at $\rho = 1$. Appendix II shows the movement of the predicted and actual values as dictated by their correlation coefficients. All predicted variables are positively correlated with actual except for three endogenous variables; net trade of beef from the U.S. to the rest of the world, U.S. demand for slaughter cattle and U.S. price of feeder cattle, that have negative correlation co-efficients. 36 out of 53 variables have correlation co-efficients above 50 percent and 17 correlation co-efficients below 50 percent. This shows that most of the predictive values move positively with the actual values with the exception of three variables. Cranfield (1995) had 18 to 15 variables with ratios above and below 50 percent respectively. The difference in data periodicity could be responsible for the increase in accuracy in prediction since more seasonality is captured with quarterly data as oppose to annual data.

5.3.2 The Root Mean Square Error (RMSE) and the Percentage RMSE (PRMSE)

This statistics show the error of prediction by providing the extent of the deviation of the predicted values from the actual. The accuracy of the prediction is observed from the difference between the actual and predicted data. Thus a lower RMSE is more accurate than a higher one. The problem is deciding on the threshold of a higher value, which this statistic does not provide. The percent root mean square error compares the RMSE with the actual data to provide a vivid understanding of how well the prediction is. It compares the RMSE over the mean of the actual data, which normalizes the error over the sample and allows for the interpretation of the error as a percent of the actual. Larger statistical values means larger deviations and otherwise.

They are calculated as follows (Judge, 1985):

$$RMSE = \sqrt{\frac{1}{n}.\sum_{t=1}^{n}(p_t - a_t)^2} \quad (5.2) \text{ and } \quad PRMSE = \frac{\sqrt{\frac{1}{n}.\sum_{t=1}^{n}(p_t - a_t)^2}}{\bar{a}_t} \quad (5.3)$$

The results in appendix VI had thirty variables, or 57 percent of the endogenous variables below 20 percent PRMSE; 17, or 32 percent of endogenous variables above 20 percent PRMSE, but below 100 percent; and 11 percent or 6 endogenous variables above 100 percent PRMSE. Cranfield (1995) had 61.1 % of his variables with PRMSE below 20 % and 33.3 % above 20 % but below 100 %, with two variables having PRMSE values above 100 %. Again, this study has better predicted values than Cranfield (1995).

5.3.3 Mean Square Error Decomposition

The prediction errors can be broken down to show the discrepancies in the error in terms of their sources using the decomposition statistics. The three error terms contained in the mean square error (MSE) are systematic and non-systematic errors due to bias, variance and covariance. The bias term captures systematic error in the simulation, and a value of zero indicates the absence of systematic bias. Systematic bias increases as the value approaches one. The error due to the difference in the predicted and actual variance is captured by the variance term. It has a similar interpretation as the bias term. The

covariance term captures the unsystematic error, that is, errors not captured by the bias or variance term. The three error terms are normalized on MSE to sum up to one.
They are calculated as (Judge, 1985):

$$MSE = \left(\bar{p} - \bar{a}\right)^2 + \left(\sigma_p - \sigma_a\right)^2 + 2.(1-p).\sigma_p.\sigma_a$$

dividing through by MSE produces the three error terms relationship as:

$$MSE = \frac{\left(\bar{p} - \bar{a}\right)^2}{MSE} + \frac{\left(\sigma_p - \sigma_a\right)^2}{MSE} + \frac{2.(1-p).\sigma_p.\sigma_a}{MSE} = 1 \qquad (5.4)$$

$$\text{BIAS} \quad + \text{ Variance } + \text{Covariance} \quad = 1$$

where σ_i is the standard deviation of i.

Appendix VI contains the MSE decomposition results and shows that 86 % (46 variables), have a bias measure less than 0.1, and 14 % (7 variables) have bias measures greater than 0.1. 54 % (29 variables) have variance measures less than 0.1, and 46 % (24 variables) have measures greater than 0.1. The covariance measure had 83 % (44 variables) of its values above 0.7 and 17 % (9 variables) below 0.7. This study had a mean bias measure of 0.103, variance measure of 0.102 and a covariance measure of 0.774. Compared to the Cranfield (1995) model, which had a bias mean of 0.076; variance mean of 0.107; and a covariance mean of 0.817, this model on average those not perform better.

5.3.4 Theil's U- Statistics

Theil (1961) model performance measure is used further as a validation test. Its value ranges from 0 to 1, representing good to worst. It shows how the predicted fits, or unfits the actual data. This measure validates the predictive errors relative to the predictive values, which stands as a weakness, as such; Theil (1966) measure is used and allows the measure to be more than one. It is calculated as:

$$U = \frac{RMSE}{\frac{1}{n}.\sum_{t=1}^{n}\left(a_t - a_{t-1}\right)^2} \qquad (5.5)$$

U ranges from zero to infinity with a perfect fit at U=0; indifferent or no-difference at U=1; and worst scenario as U goes to infinity.

From Appendix VI, it is seen that no variable had a U- that goes to infinity, and only nine variables had U-statistics of between 0.5 and 1. All other variables had values below 0.5. These results are similar to Cranfield (1995), except for the fact that he had two variables in the worst scenario in the infinity region.

5.3.5 Regression of Actual Values on Predicted Values

Actual data were regressed on predicted values to further measure the performance of the specified model in this study. The following regression is used:

$$Y_t = \alpha + \beta . p_t + \varepsilon_t \qquad (5.6)$$

where Y_t is the dependent variable, ε_t is the error term, and α and β are estimated parameters.

Results of $\alpha = 0$ and $\beta = 1$ and $R^2 = 1$ is a good indication that the simulation perfectly predicts the actual data. However, values close to the perfect values are hardly obtained since in real life it is hard to make a 100 percent prediction. For this study, the value of β, the single coefficient T-test of $\beta = 1$, and the R^2 values are reported.

Appendix VI shows reasonable R^2 values. For the null hypothesis test of $\beta = 1$, all variables had values below the critical value of 1.644. Therefore all 53 variables were not rejected. Cranfield (1995) rejected 25 out of 36 variables based on the null hypothesis of $\beta = 1$. In terms of regressing actual values on predicted values, the current specification performs better than Cranfield (1995).

5.3.6 Graphical Presentation of Actual Versus Predicted Values.

Actual and predicted values are graphed to see how well the predicted model performed. The tracking of actual values by the predicted my not emphasize the magnitude of the differences in data due to the scaling issues. However, the nature of the movement of the two can be seen. Appendix VII contains the graphs of actual and predicted values.

5.4 BSE Losses and Welfare Measures in Canada and the U.S.

To determine the effects of trade and the BSE crisis on the Canadian beef/cattle trade, simulations are performed by shocking the base model. The analysis constrained the beef and cattle trade volumes during the BSE era to those of 2002. The 2002 trade volumes in beef and cattle are used as constant base values and considered exogenous for the period 2003 to 2005.

Model variables simulated for the BSE years are: Cows and bulls, and steers and heifers supply; prices of cow and bull, prices of steer and heifer, beef price and per capita beef disappearance; total beef disappearance and quantity of beef produced in western Canada, eastern Canada and the U.S. Carcass weights for all animal types and total cattle slaughter in all three regions, and cow-calf benefits, producer and consumer surpluses and processors profit were also part of the variables simulated. The trade variables that are considered exogenous and taken out of the simulations are: Net trade in steer and heifer, and cow and bull supply between Canada and the U.S and represented by farm supply identities; net trade in beef between Canada and the U.S represented by price of beef in Canada equation. Simulation results are presented in Table 5.23.

This section also attempts to satisfy the last objective of this study by using the simulation model developed in this chapter to measure welfare gains and losses due to BSE for the period 2002-2005. The impact of BSE on consumer and producer surplus, and processors profit is measured by holding the 2002 Canada's trade volumes in beef and cattle constant for 2003-2005. The three welfare scenarios are used as money metric measure to calculate the impact of BSE on producers, processors and consumers welfare.

Producer surplus is used to measure fed-cattle producer profit and the difference between the revenue from the sale of culled cows and bulls and feeder cattle, and the cost of production is used to measure the welfare benefits of cow calf operations. The difference between price and marginal cost provides the per unit profit made by processors when marginal cost is constant. When this margin is multiplied by the quantity of beef produced, the outcome is a measure of processor's profit or returns to fixed factors of production (Cranfield 1995). The change in consumers' surplus provides the money metric welfare measure of the effect of BSE for the period 2003-2005.

The producer surplus is defined as:

$$PS = E(P) \cdot Q - \int_0^Q P^{FS}(Q) \partial(Q) \tag{5.1}$$

Where P = producer price

Q = quantity supplied

P^{FS} (Q) = price dependent farm supply equation.

Using the adaptive price expected decision in terms of supply estimations means the price used in the estimation would have to be expected price, as such one quarter lagged price is used. Therefore the producer surplus equations for fed cattle for the three regions are as follows:

Western Canada:

$$\begin{aligned} PS^{WC} &= PSH1(-1) \cdot SH1 \cdot CWS1 - 0.5 \cdot PSH1(-1) \cdot CWS1 \cdot (SH1 - \alpha_{41} - \alpha_{412} \cdot \\ &INV1(-1) - \alpha_{413} \cdot PF1(-1) - \alpha_{414} \cdot D_2 - \alpha_{415} \cdot D_3 - \alpha_{416} \cdot D4 - \alpha_{418} . SH1(-1) \end{aligned} \tag{5.12}$$

Eastern Canada:

$$\begin{aligned} PS^{EC} &= PSH2(-1) \cdot SH2 \cdot CWS12 - 0.5 \cdot PSH2(-1) \cdot CWS2 \cdot (SH2 - \alpha_{51} - \alpha_{512} \cdot \\ &INV2(-1) - \alpha_{513} \cdot PF2(-1) - \alpha_{514} \cdot D_2 - \alpha_{515} \cdot D_3 - \alpha_{516} \cdot D4 - \alpha_{518} . SH2(-1) \end{aligned} \tag{5.13}$$

The U.S.

$$\begin{aligned} PS^{US} &= PSH3(-1) \cdot SH3 \cdot CWS3 - 0.5 \cdot PSH3(-1) \cdot CWS3 \cdot (SH3 - \alpha_{61} - \alpha_{612} \cdot \\ &INV3(-1) - \alpha_{613} \cdot PF3(-1) - \alpha_{614} \cdot D_2 - \alpha_{615} \cdot D_3 - \alpha_{616} \cdot D4 - \alpha_{618} . SH3(-1) \end{aligned} \tag{5.14}$$

All variables are as previously defined with details in appendix I.

Cow calf and feeder calves' profit emanating from their sales is measured by first of all, dividing the supply of steer and heifer by 0.95 percent to arrive at the total calf crop for the previous year reflecting a 5 % mortality rate for calves as used by Goddard (1979) and Cranfield (1995). This is because calf supply was not endogenized. The total is then divided by the breeding herd inventory for the corresponding year to arrive at the calving rate for the region in question. This figure is multiplied by inventory during the simulation to estimate the calf crop.

The cost of production per cow was used to account for cow-calf operations costs. This was obtained from the 2002 Western Beef Development Centre Study for western Canada; 2003 Ontario Ministry of Agriculture, Food and Rural Affairs Cost of Production estimates; and the USDA, ERS 2001 cow-calf production cost study.

Therefore, Non-fed cattle producer profit relationship is calculated as follows:

Western Canada:

$$\begin{aligned} NFC^{WC} &= PCB1(-1)\cdot CB1\cdot CWC1 + PFC1(-1)\cdot INV1(-1)\cdot 0.17\cdot 0.6 \\ &\quad - COST1\cdot INV1(-1) \end{aligned} \tag{5.15}$$

Eastern Canada:

$$\begin{aligned} NFC^{EC} &= PCB2(-1)\cdot CB2\cdot CWC2 + PFC2(-1)\cdot INV2(-1)\cdot 0.32\cdot 0.6 \\ &\quad - COST2\cdot INV2(-1) \end{aligned} \tag{5.16}$$

The U.S.

$$\begin{aligned} NFC^{US} &= PCB3(-1)\cdot CB3\cdot CWC3 + PFC3(-1)\cdot INV3(-1)\cdot 0.27\cdot 0.5 \\ &\quad - COST3\cdot INV3(-1) \end{aligned} \tag{5.17}$$

Where COSTi is the cost of production per cow and i= 1, 2,and 3; representing western Canada, eastern Canada and the U.S. The 0.6 used to multiply feeder calf revenue represents the corresponding average weight for the class of animal in thousand pounds (Cranfield, 1995). The lagged price is to reflect the adaptive price expectation process in price setting behaviour.

The processors profit is defined for Canada, the U.S. and North America due to data availability for retail price of beef.

Canada:

$$PP^{C} = (RPBF12 - MC1)\cdot(QB1) \tag{5.18}$$

U.S.

$$PP^{US} = (RPBF3 - MC3)\cdot(QB3) \tag{5.19}$$

North America:

$$PP^{NA} = (RPBF3 - MC3)\cdot(QB1 + QB2 + QB3) \tag{5.20}$$

Consumer surplus is defined as:

$$CS = \int_0^Q P^{RD}(Q)\partial(Q) - P\cdot Q \tag{5.21}$$

Where P = retail price of beef price

Q = per capita disappearance

P^{RD} (Q) = price dependent retail demand equation.

The simulation model is used to address objective three of this thesis. The results are compared with the base model so that the extent of change in producer surplus, processors' profit and consumer surplus can be determined. The results are reported in Table 5.24 showing the mean quarterly changes in these welfare measures for the 3 years simulated.

Table 5.23 show mean changes in prices and quantity of beef and cattle in Canada and the U.S. due to BSE. Cow and bull supply, and steer and heifer supply and cow and bull inventories increased in western and eastern Canada and the U.S. Cow and bull slaughter, steer and heifer slaughter and total cattle slaughter also increased in all the regions due to the impact of BSE. This portrays what happened during the BSE era where excess capacity or supply at the farm gate drove prices down in Canada. Prices of steer and heifer, cow and bulls, feeder cattle and price of steers dropped in Canada and increased in the U.S.

A Price increase in beef of 0.186 dollars and 0.02 dollars per kilogram in Canada and the U.S., respectively is experienced due to lack of trade and border closure. The price increase is felt more in Canada than in the U.S. because of the incident of the disease in Canada. Per capita beef disappearance decreased in Canada with 2.5kg and 0.19kg in the U.S. The decrease in per capita beef consumption in the U.S. is due to the decrease in the beginning of the twelve quarter sample out weighing the decrease at the end of the sample. Total beef disappearance also decreased by 79 million kg in Canada and 56 million kg in the U.S. Losses in Canada is seen to surpass that of the U.S. Total beef production recorded a fall of 3.9 million kg, 0.98 million kg and 4.9 million kg in western and eastern Canada, and Canada as a whole; while an increase of more than 86 million kg is experienced in the U.S. Net trade to the rest of the world from the U.S. also increased due to lack of trade with Canada.

Table 5.24 shows that within the 3 year period, western Canada cow calf ranchers profit fell by a quarterly mean average of 1.26 million Canadian dollar and eastern Canada ranchers profit also fell by a quarterly mean average of 0.876 million dollars. The U.S. cow-calf ranchers' benefits increased by a mean average of 200 million U.S. dollars within the twelve quarters under consideration. Producer surplus as measured from fed cattle profit had a reduction of 5.58 million dollars in western Canada. A mean loss in producer surplus of about 1.85 million dollar in eastern Canada and a gain of 11.83 million dollars in the U.S. is recorded.

It can therefore be concluded that the effect of BSE has decreased cow-calf benefits and fed cattle producer surplus in western and eastern Canada and an increased of these benefits in the U.S. This is expected as the shock of BSE was felt more in Canada where the disease was first reported in North America than in the U.S.

Beef processors profit increased by 198 million dollars in Canada, 69 million dollars in the U.S. and 58 million dollars in North America. Consumer surplus reduced by a mean of 43 dollars in Canada and 28 dollars in the U.S as a result of the effects of BSE.

Table 5.23 Changes in Prices and Quantity of Beef and Cattle in Canada and the U.S. Due to BSE Using 2002 Trade Values as Base. (2003-2005)

Name of Variable	Western Canada	Eastern Canada	Canada	U.S.
	Mean	Mean		Mean
Cow and bull supply (Head)	27674.5	9632.417		35030.845
Steer and heifer supply(Head)	93297.195	29089.728		23525.702
Cow and bull inventory(Head)	2975.086	67.931		202608.333
Cow and bull slaughter (Head)				72337.762
Steer and heifer slaughter (Head)	10606.06	2625.022		159144
Total cattle slaughter (Head)	15538.49	5842.751		231481
Price of beef ($/kg)			0.1864	0.0159
Price of steer and heifer($/cwt)	16.78*	14.06*		23.59
Price of cow and bull($/cwt)	20.87*	46.72*		19.52
Price of feeder cattle($/cwt)	19.05*	10.43*		20.86
Price of steers($/cwt)	16.79*	13.61*		26.33
Carcass weight, Steer (kg)	0.061	0.068		2.378
Per capita beef disappearance (kg)			2.5062*	0.1920*
Total beef disappearance (kg)			79.772m*	56.258m*
Total beef production (kg)	3.923m*	0.986m*	4.909m*	86.518m
Net trade in beef, ROW (kg)				219.063m

Values with asterisks are losses incurred due to BSE, and others are increments.
M = million

Table 5.24 Welfare Changes in Canada and the U.S. Due to BSE Using 2002 Trade Values as Base. (2003-2005)

Welfare Measures	Western Canada	Eastern Canada	Canada	U.S.	North America
	Mean	Mean	Mean	Mean	Mean
		In million dollars			
Cow-Calf benefits	1.26	0.876		200.18*	
Processors profit			198.28*	69.38*	58.51*
Consumer surplus			43.83*^{D}	28.25*^{D}	
Producer surplus	5.58	1.85		11.83*	

Values with asterisks are Gains or profits made due to BSE and border closure, and others are losses
D = Dollars

5.5 Summary

In this chapter, an econometric model of the Canadian, U.S. and the aggregated North American beef industry consisting of retail beef demand, supply and supply response, processors input demand, regional and North American oligopoly-oligopsony power, and cost economies were estimated. A simulation exercise was performed to validate the model estimated over the period of 1980:1 to 2005:4, and the base model shocked in order to estimate losses in beef and cattle trade due to BSE. Demand response with respect to increase price was negative and significant for Canada and the U.S., and a substitution relationship seen in beef price with chicken and pork for both countries except for beef and pork in Canada that shared a complementary relationship. Demand estimates and their elasticities were found to be larger in the pre-BSE era compared to the entire sample estimates.

From the supply response estimations, which are estimated under an adaptive expectation framework by the use of lagged dependent variables, it is found that farmers treat cow and bulls as investment or production goods hence the price coefficient were carrying a negative sign. Steer and heifers are considered consumption goods and are raised for market hence the positive relationship of supply with price. The coefficient on capital from the inventory equation is indicative of farmers need of immediate returns hence they discount the future for the present, which reduces inventory.

A key finding from the oligopoly-oligopsony estimation is the fact that the output market structure for beef is not significantly non-competitive in the regional estimates since the hypothesis of oligopoly was rejected, but that of the input market for cattle is significantly non-competitive as indicated by their conjectural elasticities (CE). Even though the conjectural elasticites and Lerner indices (LI) varied from one quarter to another, the average results show that there is insignificant oligopoly power in the regions. The North American estimates on both Oligopoly and oligopsony were significant, indicating lack of competitiveness in the beef packing industry in North America. Quarterly CEs are graphed and presented in appendix II to IV. However, oligopsony power was relatively small and significant in all regions and in the North American estimate. This shows a minimal oligopsony power exertion especially in the U.S. and in North America.

Key results from the cost economies estimation show that no region operates a constant return to scale production, albeit approximately close to it. All regions observe diseconomies of scale as reported in the B hypothesis coefficient being positive, which tells us that marginal cost is greater than average cost. The implication is that rise in concentration affects prices through a rise in both oligopoly-oligopsony power and costs, and an amplification of the oligopolistic-oligopsony power of processing firms making prices a function of both oligopoly-oligopsony power and increasing cost of production.

The simulation results show that most of the predicted values were close to the actual values with some slight variations. The RMSE show smaller prediction errors. Taking from the mean values, the PRMSE showed some systematic errors of the model from the bias measure. The Theil-U statistics was impressive and had a good fit of the predicted to the actual values since none of the variable had a value greater than one. The regression of actual versus predicted values produced a high R^2 value for all variables and the hypothesis test of $\beta = 1$ was not rejected for any of the variables.

The trade shock introduced showed by how much prices and supply of beef and cattle would have changed without BSE if 2002 trade figures were held constant for 2003 to 2005. Simulation results for 2003-2005 showed that there was significant increase in supply of cattle in Canada and the U.S. Also, prices of steer and heifer and cow and bulls declined. Per capita beef disappearance would have increased in Canada, while beef prices would have decreased. Beef production would have increased in Canada and decreased in the U.S., and total beef disappearance would have decreased in both countries.

The simulation of the econometric model developed in this study was used to determine welfare measures for producers, processors and consumers. Holding all trade variables as exogenous variables at constant 2002 values and simulating 2003-2005, it was found that ranchers' cow calf benefits and fed cattle producer surplus fell in Canada and increased in the U.S. Beef processors' profit fell in Canada, the U.S. and in North America. A mean loss in consumer surplus was found in both Canada and the U.S. of about 43 dollars and 28 dollars, respectively.

Chapter Six: SUMMARY AND CONCLUSIONS

6.1 Introduction

This chapter contains the summary of the entire thesis, discussion and implications of the results obtained in the previous chapters of this study. The contribution of these results, and possibilities for further research on market competition and cost economies are discussed. Conclusions are drawn with reference to the results obtained from this study and the accuracy of the simulations performed. The limitations of this study are highlighted and recommendations for marketing and pricing policies as they affects market competitions are suggested.

6.2 Summary, Discussions and Conclusions.

Chapter one contains an overview of the beef industry and market competition as it affects the pricing of cattle and beef in this important industry in Canada and North America. The existing pricing problems in the beef industry were further aggravated by the incidence of BSE in 2003 in Alberta, which led to a series of complaints and petitions about unfair pricing by beef packing plants to farmers. The problem of overcapacity due to border closures saw plummeting cattle prices at the farm level despite the fact that beef prices and consumption didn't necessary declined. Therefore, the need to look into this market and try to analyze the market in terms of its structure and conduct while considering the increasing costs that accompanied these changes became obvious.

The problem statement now becomes how to analyze these market conditions and try to provide answers to issues arising out of the potential lack of competition in the beef industry or to determine whether costs of production are taking all the profits. With few studies in the Canadian context recently on market competition, and none of these studies have tried to estimate cost economies or a joint estimation of possible mark-up and mark-down pricing behaviours, this study tried to answer and cover this gap. In this study estimation of the market structure and pricing in the beef industry was done econometrically; a determination of the presence or absence of market power and whether costs have been playing any part in mark-ups or mark-downs in beef and cattle prices, respectively; and the effect of BSE in terms of losses or gains to consumers', cow-calf ranchers, fed cattle producers and processors in the North American beef cattle industry are presented. Considering the importance of this industry to the Canadian economy, results from this kind of study could help enhance policy formation that might influence local and international demand for beef in Canada.

Relevant literature was reviewed in chapter two as it relates to market competition particularly in the Canadian and North American beef industry. The effects of BSE in terms of trade regulation and their distortions on market equilibria were graphically analyzed in the North American beef and cattle industry context. This was followed by a concise review of market power models with much emphasis on the conceptual framework of the C.V. model. Different North American oligopoly and oligopsony models were reviewed in terms of their methodologies, objectives, data used and general results and contributions to the literature. Chapter three consisted of the development of a conceptual model that incorporates all the actions of the players in the beef industry viz: the consumers' retail demand, farm supply response process for cattle and the processors' profit maximization behaviour upon which the empirical estimation was based. A schematic framework of the entire composite model was presented and market closing identities were developed for the closure of the entire model. This was to help establish market equilibrium to use to validate results and test for different welfare measures.

Data description and the exposition of the entire conceptual model as regards to hypotheses and a priori expectations of the model were the issues in chapter four. Retail beef demand, cattle supply and inventories, price linkage equations between Canada and the U.S., and carcass weight equations were specified and estimated. Their elasticites were compared to those of previous studies to ascertain consistencies and trends over the years. Processors input demand equations and cost economies equations were all simultaneously estimated alongside the demand, supply and price linkage equations using LSQ, and FIML procedures. The estimations were done for western Canada, eastern Canada, the U.S. and North America for the period 1980 to 2005 using quarterly time series data.

The estimation results in chapter five showed that most of the estimation coefficients and elasticities, from the farm supply to retail demand, are statistically significant and theoretically within acceptable levels in terms of signs and magnitude.

The likelihood ratio test confirms few auto-correlation problems and equations with problems were corrected for auto-correlation. The simulation results helps provide indicators of the models' accuracy and the appropriateness of model use for making market policy decisions. This is to ensure that a subsequent analysis, which depends on these estimates, will be robust.

Following the objectives of this thesis, of which number one is to determine the structure of the North American beef-cattle industry econometrically, results confirm that the market structure is significantly oligopolistic and oligopsonistic in North American. However, regional estimates seem to be insignificant in terms of oligopoly power but significantly oligopolistic from the processor beef supply side. All estimates were below 0.3 except for the conjectural elasticity estimate for the U.S. which was 0.533.

Objective number two is to estimate the price-cost margin or market power exertion in both the demand and supply market for cattle and beef, respectively, and to determine processors' cost economies. This was estimated by the Lerner index, which shows by how much prices have risen above marginal costs. On the beef supply side, retail prices were significantly above marginal cost in North America but not in western and eastern Canada, and the U.S. It is also significant on the cattle demand side for all regions. The order of oligopsony power from high to low is: western Canada, eastern Canada, the U.S. and North America. Still, following the magnitude of the estimates from all the regions, price mark-down to farmers is smaller compared to the mark-ups to retailers/ consumers.

Hypothesis test were carried out in order to find out if the non-competitive industry structure and market power exertion is due to the increasing costs of production in beef packing and processing or otherwise, and if cost economies are a driving force for consolidation in this industry. All regional estimates show significant diseconomies of size, and none of the regions exhibit a constant return to scale technology. A further test of the cost economies estimates revealed that in all three regions, marginal costs are greater than their average costs, which is a case of diseconomies of scale. However, only in western Canada and North America were these estimates statistically significant. For these regions, both market power and costs of production affects price.

The third objective is to introduce trade shocks to the model and simulate in order to determine welfare changes associated with the 2003-2005 BSE era. The first simulation was a situation of no trade due to BSE, which was used as the base simulation. The second constrained simulation was where trade was assumed by holding the 2002 trade figures constant for the years 2003-2005. Despite the fact that this is a conservative restriction or shock, the simulation results revealed significant losses in term of cattle supply, cattle and beef prices and beef production in Canada. The U.S on the other hand recorded gains between 2003 and 2005 due to the BSE crisis. Further simulations to examine welfare benefits for producers, processors and consumers was conducted. It was found that ranchers' cow calf benefits and fed cattle producer surplus fell in Canada and increased in the U.S. Beef processors' profit fell in both countries and in the composite North American beef processing industry. Consumer surplus was found to have decreased in both countries with that of Canada more than the U.S. for the three year period ranging from 2003-2005.

Lastly, this study's results were compared to Cranfield (1995). This study used a quarterly time series and estimated both regional and North American oligopoly/oligopsony market power and cost economies, as opposed to Cranfield's (1995) use of annual data and a North American oligopoly estimation. Cranfield (1985) found the exercise of oligopolistic market power in the North American beef cattle industry, and this study found the same thing in the North American estimation. However, this study's estimate is smaller than that found in Cranfield (1995). Significant oligopsony market power existed in all regional and North America estimations. This is in line with the findings of Anders (2005), of both oligopoly and oligopsony market power in the German retail industry using a joint simultaneous estimation such as that used in this study. Similar to Cranfield's (1995) study, in this study welfare measures for producers, processors and consumers of cattle and beef in Canada and the U.S. are calculated. While this study calculated welfare measures for the three years of BSE border closures from 2003-2005, the former calculated welfare measures with respect to changes in brand and generic advertisement expenditure on beef. This benefit measure can be used to determine policy options for the beef cattle industry in North America in terms of compensations and assistance programs so that the right people are targeted and given commensurate compensation and assistance, especially in crisis situations.

6.3 Contribution of this Study

Until now, there have been no published studies in Canada that has tried the extension of a C.V. model to capture the simultaneous estimation of joint exercise of the oligopoly and oligopsony power. Most Canadian studies have concentrated on oligopoly and a few have also looked solely at oligopsony situations. In the U.S., this body of literature was started Shroeter (1988). Therefore, this would help in describing not only the cattle demand side, but also the beef supply side from the cow-calf operators, feedlots and processors

Another contribution of this study is the fact that it is also the first to estimate cost (scope) economies in Canadian and North American beef packing plants and their effects on market competition. Lopez *et al* (2002) and studies in the U.S. by Morrison (1999, 2000, 2001a, 2001b, 2003) have done extensive work on cost economies in the beef packing and processing industries. Except for this study, no study of this nature has been carried out in Canada as part of a North American single entity.

One of the most important contributions of this thesis is the pricing data generation methodology used in this study, which developed prices of different beef cuts to build an entire carcass cut out value for different types and sexes of cattle. No study has generated such a detailed data set for beef prices with the exception of Scott (1983) in Canada.

The simulation results, despite been based on a conservative assumption and restriction, provided quantitative and monetary estimates of the losses and gains for both Canada and the U.S. from BSE. These estimates could be used as guides when making policy decisions under such disaster situations.

6.4 Limitations to this Study

A number of limitations exist as far as this study is concerned, which range from data availability and construction, the estimation procedures and restrictions imposed during estimation. The assumption that entry barriers are only a result of cost differentials between existing firms and potential entrants, which consequently leads to market power exertion could be flawed if other costs such as branding, packaging and advertisement are not considered.

The use of a quarterly sample size could reduce the flexibility of the results as monthly data could increase the understanding of variability in the market in this study.

Another limitation to this study is the assumption that other countries trade in cattle and beef with North America is considered exogenous. This is not the case in real life because trade in cattle between Canada and U.S. with Mexico is significant and exports and imports from Australia, New Zealand into Canada and the U.S. are also huge. Therefore endogenizing trade numbers and values for these other regions could affect the variability of results obtained in this study.

The restrictions on the trade quantities used in the simulations, which restricts the 2003-2005 trade figures to those of 2002 could be based on false assumption that the targeted period would be identical with the recent past. Further simulations with a variety of trade levels that might have existed in that period might shed some light on the standard errors associated with the presented results.

6.5 Further Research

Drawn from the limitations of this study, more research is needed in terms of incorporating product heterogeneity into the model. Also, all other trade partners, especially the ones mentioned earlier need to be endogenized in the model. This would probably produce more accurate estimates.

This estimation need to be further investigated in the retail sector as some studies have indicated market power in the retail industry (Anders, 2005) as well. The need for firm level data cannot be over emphasized in terms of determining market competition and market power. This is because this regional aggregation can not fully depict the actions of firms and individuals in this industry, hence providing only aggregate results.

Finally, models could be built to compare the different cost functions available in terms of variability in results.

REFERENCES

Aadland, David and DeeVon, Bailey. 2001. Short-Run Supply Responses in the U.S. Beef-Cattle Industry. *American Journal of Agricultural Economics* 83, no. 4: 826-40.

Agriculture and Agri-Food Canada. 1979-2005. "Livestock and Meat Trade Report", Ottawa, Ontario. Canada.

Alberta Beef Producers. Various Issues. 2004-2005. The Alberta Beef Producers.

Alberta Beef-Focussing on the Future. "A Strategic Framework for Repositioning the Industry". April 30, 2004.

Alston, Julian M., and James A. Chalfant. 1991. Can We Take the Con Out of Meat Demand Studies? *Western Journal of Agricultural Economics* 16, no. 1: 36-48.

Anders, Sven. 2005. "Measuring Market Power in German Food Retailing." Discussion Papers in Agricultural Economics 80, Institute of Agricultural Policy and Market Research, University Giessen.

Appelbaum, Elie. 1982. The Estimation of the Degree of Oligopoly Power. *Journal of Econometrics* 19, no. 2-3: 287-99.

Arzac, Enrique R., and Maurice Wilkinson. 1979. A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of Its Policy Implications. *American Journal of Agricultural Economics* 61, no. 2: 297-308.

Atkins, F. J., W. A. Kerr, and D. B. McGivern. 1989. A Note on Structural Change in Canadian Beef Demand. *Canadian Journal of Agricultural Economics* 37, no. 3: 513-24.

Azzam, Azzeddine. 1996. Testing the Monopsony-Inefficiency Incentive for Backward Integration. *American Journal of Agricultural Economics* 78, no. 3. 585-590.

Azzam, Azzeddine M., and Emilio Pagoulatos. 1990. Testing Oligopolistic and Oligopsonistic Behaviour: An Application to the U.S. Meat-Packing Industry. *Journal of Agricultural Economics* 41, no. 3: 362-70.

Azzam, Azzeddine M., and John R. Schroeter. 1991. Implications of Increased Regional Concentration and Oligopsonistic Coordination in the Beef Packing Industry. *Western Journal of Agricultural Economics* 16, no. 2: 374-81.

Azzam, Azzedine M. 1997. Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration. *The Journal of Industrial Economics* 45, no. 4: 377-386

Azzam, Azzedinne M, and John R. Shroeter. 1995. The Trade-off Between Oligopsony Power and Cost Efficiency in Horizontal Consolidation: An Example from Beef Packing. *American Journal of Agricultural Economics* 77, no. 4: 825-36.

Azzedine Azzam, and Emilio Pagoulatos. 1999. Measurement of Technological and Market Structure-Alternative Methodological Perspectives: Discussion. *American Journal of Agricultural Economics* 81: 644-46.

Beck, Roger L, and Sheila Mozejko. 1992. Concentration and Price/Cost Margins Across Time in Canada. *Revue Canadienne Des Sciences De L'Administration* 9, no.1: 40-48.

Beef Information Centre. 2004 and 2005. "Canada's Cattle Beef Industry". Beef Information Centre.

Ben-Kaabia, M., and Jose M. Gil. 2007. Asymmetric Price Transmission in the Spanish Lamb Sector. *European Review of Agricultural Economics* 34, no. 1: 53-80.

Bessler, David. 2005. A Time Series Analysis of Canadian Cattle and Beef Prices and Quantities Prior to and Following the May 2003 Discovery of BSE in the Canadian Cattle Herd. Economic Reports Prepared for the Competition Bureau, Canada.

Bhuyan, S., and R. A. Lopez. 1997. Oligopoly Power in the Food and Tobacco Industries. *American Journal of Agricultural Economics* 79, no. 3: 1035-43.

Bierman, S. H., and Luis Fernandez. 1998. *Game Theory with Economic Application.* 2nd ed., 452pp. Addison-Wesley.

Bresnahan, Timothy F. 1989. *Empirical Studies of Industries with Market Power.* Volume 2 ed., 1011-57. Vol. 2, Chapter 17. Elsevier.

Brocklebank, Andrea and Hobbs, Jill E. 2004. Building Brands: Supply Chain Alliances in the Canadian Beef Industry. Report Prepared for Canfax Research Services.

Bunte, Frank, and Jack Peerlings. 2003. Asymmetric Price Transmission Due to Market Power in the Case of Supply Shocks. *Agribusiness* 19, no. 1: 19-28.

Canadian Cattlemen Association, 2004-2005. "Canada's Cattle Beef Industry."Canadian Cattlemen's Association.

Canadian Food Inspection Agency (CFIA). "New Regulations Proposed for the BSE-Related Feed Controls." Web Page, Accessed on 19th of Dec., 2004. at http://www.inspection.gc.ca/english/corpaffr/newcome/2004/20041210e.shtml

CANFAX Weekly Summary on Boxed Beef Prices For Canada and the U.S., 2002-2005.

CANFAX Statistical Briefer, CANFAX Research Service, Calgary, Oct. 2006

Carlton, D. W., and J.M. Perloff. 2000. *Modern Industrial Organization*. 3rd ed. Addison-Wesley Longman.

Chalfant, James A., Richard S. Gray, and Kenneth J. White. 1991. Evaluating Prior Beliefs in a Demand System: The Case of Meat Demand in Canada. *American Journal of Agricultural Economics* 73, no. 2: 476-90.

Chambers, Robert G. 1991. *Applied Production Economics*. New York, New York: Cambridge University Press.

Chavas, Jean-Paul. 1983. Structural Change in the Demand for Meat. *American Journal of Agricultural Economics* 65, no. 1: 148-53.

Chen, P. Y., and M. M. Veeman. 1991. An Almost Ideal Demand System Analysis for Meats with Habit Formation and Structural Change. *Canadian Journal of Agricultural Economics* 39, no. 2: 223-35.

Chern, W.S., E.T.Loehman, ands.T. Yen. 1995. *Information, Health Risk Beliefs, and the Demand for Fats and Oils*. Review of Economic and Statistics 77, no. 3:555-64.

Coleman, J. R., and Karl D. Meilke. 1988. The Influence of Exchange Rates on Red Meat Trade between Canada and the United States. *Canadian Journal of Agricultural Economics* 36, no. 3: 401-24.

Corporate Research Project of Good Jobs First. "What's the Beef? Consolidation and Market Manipulation in the Beef Packing Industry" Corporate Research E-Letter No. 45, March 2004.

Cranfield, J. A. L., and E. W. Goddard. 1999. Open Economy and Processor Oligopoly Power Effects of Beef Advertising in Canada. *Canadian Journal of Agricultural Economics* 47, no. 1: 1-19.

Cranfield, John A. L. 1995. "Advertisement and Oligopoly Power in the North American Beef Industry". Unpublished MSc. Thesis, University of Guelph, Guelph Ontario.

Cranfield, John., Linda Cousineau, Mike Swidinsky, Huiwen Lai, Ellen Goddard and James Rude. 1995. Oligopoly Power in the Cnadaian Food Processing Industry-Further Results. Department of Agricultural Economics and Business, University of Guelph. Working Paper WP95/02.

Deaton, A.S., and J. Muellbauer. 1980. *Economics and Consumer Behaviour*. New York: Cambridge University Press.

Dhar, Tirtha, Jean-Paul Chavas, Ronald W. Cotterill, and Brian W. Gould. 2005. An Econometric Analysis of Brand-Level Strategic Pricing between Coca-Cola Company and PepsiCo. *Journal of Economics and Management Strategy* 14, no. 4: 905-31.

Dhar, Tirtha P. and Cortterill, Ronald W. 2002. Price Transmission in Differentiated Product Market Channels: A Study of the Boston Fluid Milk Market and the North East Dairy Compact. Food Marketing Policy centre Research Report No. 67.

Dixit, Avinash K. 1986. Comparative Statics for Oligopoly. *International Economic Review* 27, no. 1: 107-22.

Dockner E., Jorgensen S. Van Long N. and Sorger G. 2000. *Differential Games in Economics and Management Science*. Boston: Cambridge University Press.

Driscoll, P. J., S. M. Kambhampaty, and W. D. Purcell. 1997. Nonparametric Tests of Profit Maximization in Oligopoly with Application to the Beef Packing Industry. *American Journal of Agricultural Economics* 79, no. 3: 872-79.

Druhan, Patrick James. 1992. "Price Symmetry in the Canadian Beef, Chicken, and Egg Markets: Implications for Market Power". Unpublished MSc. Thesis, Macdonald College of McGill University, Ste. Anne-de-Bellevue, Quebec.

Dufwenberg, Martin, and Uri Gneezy. 2000. Price Competition and Market Concentration: An Experimental Study. *International Journal of Industrial Organization* 18, no. 1: 7-22.

Eales, James. 1996. A Symmetric Approach to Canadian Meat Demand Estimation. *Journal of Agricultural and Resource Economics* 21, no. 2: 368-80.

Elitzak, H. 1996. Food Cost Review, *Agricultural Economics Report No. 729*, U.S. Department of Agriculture, Stanford, California.

Feinberg, Robert M. 1980. The Lerner Index, Concentration, and the Measurement of Market Power. *Southern Economic Journal (Pre-1986)* 46, no. 4: 1180.

Friedman, J.W. 1983. Limit Price Entry Prevention When Complete Information Is Lacking. *Journal of Economic Dynamics and Control* 5 , 187-199

Friedman, J. W. 1990. Game Theory with Applications to Economics. 2nd ed. New York: Oxford University Press.

Fudenberg, Drew, David K. Levine, and Jean, Tirole. 1987. Incomplete Information Bargaining with Outside Opportunities. *The Quarterly Journal of Economics* 102, no. 1: 37-50.

Gardner, B. L. 1975. Farm Retail Price Spread in a Competitive Food-Industry. *American Journal of Agricultural Economics* 57, no. 3: 399-409.

George, P.S., and King, G.A.(1971). Consumer Demand for Food Commodities in the United States with Projections for 1980. GianninFoundation Monograph 26 :530-67.

Goddard, Ellen. 1979. Comparative Analysis of Supply Management and Stabilization Programs in the Canadian Livestock Sector with Implications for the Processing Sector. MSc. Thesis, University of Guelph, Guelph, Ontario.

Goddard, Ellen W., and Brian Cozzarin. 1992. A Preliminary Look at Advertising Beef, Pork, Chicken, Turkey, Eggs, Milk, Butter, Cheese, and Margarine in Canada. *Commodity advertising and promotion.* Henry W. Kinnucan, Stanley R. Thompson, and Hui-Shung Chang, 120-138. Ames: Iowa State University Press.

Goddard, E.W. , G.R. Griffith, and J.J. Quilkey. 1992. *Optimal Advertising Investment in Australia and Canada.* Economic Service Unit, New South Wales Department of Agriculture Series 2/92.

Gohin, Alexandre, and Herve Guyomard. 2000. Measuring Market Power for Food Retail Activities: French Evidence. *Journal of Agricultural Economics* v. 51, no. 2: 181-95.

Goodwin, Barry K., and Matthew T. Holt. 1999. Price Transmission and Asymmetric Adjustment in the U.S. Beef Sector. *American Agricultural Economics Association* 81, no. 3: 630-637.

Grier, Kevin. 2005. Analysis of the Cattle and Beef Markets Pre and Post BSE: Final report to the Competition Bureau. George Morris Centre.

Griffith, G. R. 2000. Competition in the food marketing chain. *Australian Journal of Agricultural and Resource Economic* 44:333–67.

Handley, Joanne 2003. Ontario Ministry of Agriculture, Food and Rural Affairs: Evaluating Your Cost of Production in the Cow Herd. Ontario.

Haskel, Jonathan, and Christopher Martin. 1994. Capacity and Competition: Empirical evidence on UK panel data. *The Journal of Industrial Economics* 42, no. 1: 23.

Hassan, Zuhair A., and S. R. Johnson. 1976. Consumer Demand Parameters for the US: A Comparison of Linear Expenditures, Rotterdam, and Double-Log Estimates. *Quarterly Review of Economics and Business* 16, no. 1: 77-92.

Hassan, Zuhair A., and Stanley R. Johnson. 1979. The Demand for Meat in Canada: An Application of the Transformation of the Variables. *Canadian Journal of Agricultural Economics* 27, no. 3: 1-12.

Hassan, Zuhair A., and L. Katz. 1975. The Demand for Meat in Canada. *Canadian Journal of Agricultural Economics* 23, no. 1: 53-63.

Holloway, Garth J. 1991. The Farm-Retail Price Spread in an Imperfectly Competitive Food Industry. *American Journal of Agricultural Economics* 73, No. 4, 979-989.

Houck, J.P. 1986. Elements of Agricultural Trade Policies. Macmillian, New York. 224pp.

Jarvis, Lovell S. 1974. Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector. *Journal of Political Economy* 82, no. 3: 489-520.

Jensen, Helen H., and John R. Schroeter. 1992. Television Advertising and Beef Demand: An Econometric Analysis of 'Split-Cable' Household Panel Scanner Data. *Canadian Journal of Agricultural Economics* 40, no. 2: 271-94.

Jones, R., Purcell, W., Driscoll, P., & Peterson, E. (1996). Issues and Cautions in Employing Behavioral Modeling Approaches to Test for Market Power (Tech. Rep.). Research Institute on Livestock Pricing, Virginia Tech. (Research Bulletin 1-96, March, 1996).

Judge, George G., W. E. Griffiths, R. Carter Hill, Helmut Lütkepohl, and Tsoung-Chao Lee. *The Theory and Practice of Econometrics*, Second ed. New York: John Wiley & Sons, 1985.

Katz, Michael L., and Harvey S Rosen. 1998. *Microeconomics*. 3rd ed. Boston: McGraw- Hill.

Koontz, S. R., P. Garcia, and M. A. Hudson. 1993. Meatpacker Conduct in Fed Cattle Pricing: An Investigation of Oligopsony. *American Journal of Agricultural Economics* 75, no. 3: 537-48.

Koontz, Stephen R., and Philip Garcia. 1997. Meat-Packer Conduct in Fed Cattle Pricing: Multiple-Market Oligopsony Power. *Journal of Agricultural and Resource Economics* 22, no. 1: 87-103.

Kulshreshtha, S. N., and A. G. Wilson. 1972. An Open Econometric Model of the Canadian Beef Cattle Sector. *American Journal of Agricultural Economics* 54, no. 1: 84-91.

Liu, Rongmin. 1991. The Estimation of Market Power in 5 Canadian Food and Beverage Industries. Unpublished MSc. Thesis, University of New Brunswick.

Lloyd, T. A., S. McCorriston, C. W. Morgan, and A. J. Rayner. 2004. *Price Transmission in Imperfectly Competitive Markets*. Discussion Paper in Economics, No. 04/09 University of Nottingham. U.K.

Lloyd, T. A., S. McCorriston, C. W. Morgan, and A. J. Rayner. 2006. Food Scares, Market Power and Price Transmission: The UK BSE Crisis. *European Review of Agricultural Economics* 33, no. 2: 119-47.

Lomeli, Jose. 2005. What Has Been Causing the Decline in Beef Consumption in Canada? MSc. Unpublished Thesis, University of Alberta.

Lopez, Ramon E. 1984. Measuring Oligopoly Power and Production Responses of the Canadian Food Processing Industry. Journal of Agricultural Economics 35, 219-230.

Lopez, Rigoberto A., Azzeddine M. Azzam, and Carmen Liron-Espana. 2002. Market Power and/or Efficiency: A Structural Approach. *Review of Industrial Organization* 20, no. 2: 115-26.

Love, Alan. 2005. An Investigation of the Effects of BSE on the Canadian Cattle and Beef Markets. Economic Reports Prepared for the Competition Bureau Canada.

MacLachlan Ian, Townshend, I. and Aitken, S. 2006. The New Generation Cooperative Model of Cattle Slaughter. Department of Geography, University of Lethbridge, Lethbridge, Alberta.

Marsh, John. M. 1984. Estimating slaughter Supply Response for U.S. Cattle and Hogs. *North Central Journal of Agricultural Economics* 6, no. 2: 18-28.

Marsh, John M. 1994. Estimating Intertemporal Supply Response in the Fed Beef Market. *American Journal of Agricultural Economics* 76, no. 3: 444-53.

———. 2003. Impacts of Declining U.S. Retail Beef Demand on Farm-Level Beef Prices and Production. *American Journal of Agricultural Economics* 85, no. 4: 902-13.

———.1992. USDA Data Revisions of Choice Beef Prices and Price Spreads: Implications for Estimating Demand Responses. *Journal of Agricultural and Resource Economics* 17, no. 2: 323-34.

Martin, Larry J., and Richard Haack. 1977. Beef Supply Response in North America. *Canadian Journal of Agricultural Economics* 25, no. 3: 29-47.

McCorriston, S., C. W. Morgan, and A. J. Rayner. 1998. Processing Technology, Market Power and Price Transmission. *Journal of Agricultural Economics* 49, no. 2: pp.185-201.

———. 2001. Price Transmission: The Interaction Between Market Power and Returns to Scale. *European Review Agricultural Economics* 28, no. 2: 143-59.

Morgan C.W, and Steve McCorriston. Market Power and Relative Adjustment: Evidence from the UK. *XIth Congress of the EAAE (European Association of Agricultural Economists) "The Future of Rural Europe in the Global Afri-Food Systems"*.Copenhagen, Denmark.

Morrison, Catherine J. P. 1999. Aggregation and the Measurement of Technological and Market Structure: The Case of the U.S. Meatpacking Industry. *American Journal of Agricultural Economics* 81: 624-29.

———. 2000. Cost Economies and Market Power in U.S. Beef Packing. *Giannini*

———. 2000. Cost Economies and Market Power in U.S. Beef Packing. *Giannini Foundation of Agricultural Economics, University of Carlifornia.* 66p.

———. 2001a. Market and Cost Structure in the U.S. Beef Packing Industry: A plant-Level Analysis. *American Journal of Agricultural Economics* 83, no. 1: 64-76

Morrison, Catherine J. P. 2001b. Cost Economies and Market Power: The Case of the U.S. Meat Packing Industry. *Review of Economics and Statistics* 83, no. 3: 531-40.

Morrison, Catherine J. P. 2003. Cost Economies: A Driving Force for Consolidation and Concentration? *Southern Economic Journal* 70, no. 1: 110-127.

Moschini, Giancarlo and Karl D. Meilke. 1989. Modeling the Pattern of Structural Change in U.S. Meat Demand. *American Journal of Agricultural Economics* 71, no. 2: 253-61.

Moschini, Giancarlo and Anuradha Vissa. 1993. Flexible Specifications of Mixed Demand Systems. *American Journal of Agricultural Economics* 75, no. 1: 1-9.

Muth, M. K., and M. K. Wohlgenant. 1999. A Test for Market Power Using Marginal Input and Output Prices with Application to the U.S. Beef Processing Industry. *American Journal Agricultural Economics* 81, no. 3: 638-46.

Nash. John. F. 1950. The Bargaining Problem. *Econometrica* 18, No. 2 : 155-162

National Farmers Union. "Submission to the Federal Competition Bureau Regarding the Proposed Takeover of Better Beef Ltd. by Cargill". June 23, 2005, Saskatoon.

National Farmers Union. Various Issues 2004 and 2005. National Farmers Union Saskatoon, Saskatchewan, Canada.

Nelson, Glenn, and Thomas Spreen. 1978. Monthly Steer and Heifer Supply. *American Journal of Agricultural Economics* 60, no. 1: 117-25.

Nerlove, Marc. 1956. Estimates of the Elasticities of Supply of Selected Agricultural Commodities. *Journal of Farm Economics* 38, no. 2: 496-509.

Nerlove, Marc, and Ilaria Fornari. 1998. Quasi-rational Expectations, an Alternative to Fully Rational Expectations: An Application to US Beef Cattle Supply. *Journal of Econometrics* 83, no. 1-2: 129-61.

Paarsch, Harry J. 1985. Micro-Economic Models of Beef Supply. *Canadian Journal of Economics* 18, no. 3: 636-51.

Quagrainie, Kwamena. 2003. Testing for Processor Market Power in the Markets for Cattle and Hogs in Canada. *Canadian Journal of Agricultural Economics* 51, no. 3: 397-411.

Reed, Albert J., and J. Stephen Clark. 1998. The Transmission of Trends in Retail Food and Farm Prices. *American Journal of Agricultural Economics* 80, no. 5: 1139-43.

Report of the Alberta Auditor General on the Alberta Government's BSE–related Assistance Programs July 27, 2004.

Report of the Standing Committee on Agriculture and Agri-Food. Final Report: Financial Analysis relative to Meat Packing Companies in the Context of the BSE Crisis of 2003. November, 2005.

Ricard, Daniel. 1976. Farm to Retail Price Spreads for Beef in Canada, Commission of Inquiry into the Marketing of Beef and Veal Report 2, Ottawa.

Canadian Trade Tribunal, August 1993. Report on Canadian cattle and beef industry. Ottawa.

Canada Livestock and Meat Trade Report. Red Meat Market Information: Monthly Livestock and Meat report. 1980-2005.

Chern, Wen.S, and Rickertsen, Kyrre. 2003. Health Nutrition and Food Demand. Cambridge, MA: CABI Publishing, 290p.

Reutlinger, Shlomo. 1966. Short-Run Beef Supply Response. *Journal of Farm Economics* 48, no. 4: 909-19.

Reynolds, Anderson, and Ellen W. Goddard. 1991. Structural Change in Canadian Meat Demand. *Canadian Journal of Agricultural Economics* 39, no. 2: 211-22.

Richard Daniels (1976). Farm to Retail Price Spreads for Beef in Canada. Commision of Inquiry into the Marketing of Beef and Veal , Report 2, Ottawa.

Rosen, Sherwin, Kevin M. Murphy, and Jose A. Scheinkman. 1994. Cattle Cycles. *Journal of Political Economy* 102, no. 3: 468-92.

Rucker, Randal R., Oscar R. Burt, and Jeffrey T. LaFrance. 1984. An Econometric Model of Cattle Inventories. *American Journal of Agricultural Economics* 66, no. 2: 131-44.

Sanjuan, A. I., and P. J. Dawson. 2003. Price Transmission, BSE and Structural Breaks in the UK Meat Sector. *European Review of Agricultural Economics* 30, no. 2: 155-72.

Sara D. Short. 2001. USDA Statistical Bulletin. Characteristics and Production Costs of U.S. Cow-Calf Operations. No.974-3: 8-17.

Schroeter, J., and A. Azzam. 1991. Marketing Margins, Market Power, and Price Uncertainty. *American Journal of Agricultural Economics* 73, no. 4: 990-999.

Schroeter, John, and Azzeddine Azzam. 1990. Measuring Market Power in Multi-Product Oligopolies: The US Meat Industry. *Applied Economics* 22, no. 10: 1365-1376.

Schroeter, John R. 1988. Estimating the Degree of Market Power in the Beef Packing Industry. *The Review of Economics and Statistics* 70, no. 1: 158-62

Schroeter, John R., Azzeddine M. Azzam, and Zhang Mingxia. 2000. Measuring Market Power in Bilateral Oligopoly: The Wholesale Market for Beef. *Southern Economic Journal* 66, no. 3: 526-47.

Scott, Carolyn M. 1983. "Analysis of price spread behaviour of red meat." Unpublished MSc. Thesis, University of Guelph, Ontario.

Sheridan Scott. Remarks to the Standing Committee on Agriculture and Agri-Food. "Study of the Pricing of Beef at the Slaughter, Wholesale, and Retail Levels, in the Context of the BSE in Canada. Feb. 16, 2004. Ottawa, Ontario.

Statistics Canada Provincial Beef Export 1980-2005. Supply and Disposition of Food in Canada. CANSIM II Database.

Steindl, J. 1952. *Maturity and Stagnation in American Capitalism*. New York: New York and London, Monthly Review Press.

Stern, Nicholas. 1987. The Effects of Taxation, Price Control, and Government Contracts in Oligopoly and Monopolistic Competition. *Journal of Public Economics* 32, no. 2: 133-158

Stiegert, Kyle W., Azzeddine Azzam, and B. Wade Brorsen. 1993. Markdown Pricing and Cattle Supply in the Beef Packing Industry. *American Journal of Agricultural Economics* 75, no. 3 : 549-58.

Sulewski, Travis, John Spriggs, and R. A. Schoney. 1994. Agricultural Producer Price Expectations. *Canadian Journal of Agricultural Economics* 42, no. 3: 301-10.

Theil, H. 1961. *Applies Econometric Forcasting.* Amsterdam, Holland: North Holland Publishing Company.

Theil, H. 1966. *Economic Forcasting and Policy.* Chicago, Illinois: Rand McNally and Company Company.

Tomek, William G. and Kenneth L. Robinson (1990). *Agricultural Product Prices*, 3rd ed. Ithaca, New York: Cornell University Press.

Tryfos, Peter. 1974. Canadian Supply Functions for Livestock and Meat. *American Journal of Agricultural Economics* 56, no. 1: 107-13.

Tryfos, Peter, and N. Tryphonopoulos. 1973. Consumer Demand for Meat in Canada. *American Journal of Agricultural Economics* 55, no. 4: 647-52.

Unterschultz, James, Kwamena K. Quagrainie, and Michel Vincent. 1997. Evaluating Quebec's Preference for Alberta Beef versus US Beef. *Agribusiness* 13, no. 5: 457-68.

U.S. Department of Justice and the Federal Trade Commission: Horizontal Merger Guidelines, Issued April 2, 1992, revised April 8th, 1997.

U.S. Department of Agriculture, Economic Resource Services (ERS) Red Meat Yearbook 94006. 1970-2005.

Wann, Joyce J., and Richard J. Sexton. 1992. Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing. *American Journal of Agricultural Economics* 74, no. 4: 980-990.

Western Beef Development Centre: 2002 Saskatchewan Cow Herd Cost of Production Analysis. Saskatchewan.

Wohlgenant, Michael K. 1985. Estimating Cross Elasticities of Demand for Beef. *Western Journal of Agricultural Economics* 10, no. 2: 322-29.

Wohlgenant, Michael K. 1989. Demand for Farm Output in a Complete System of Demand Functions. *American Journal Agricultural Economics* 71, no. 2:241-252

———. 2001. Marketing margins: Empirical analysis. *Handbook of Agricultural Economics.* Volume 1, Part 2 ed., 933-70. Elsevier.

Xu, Xiaosong, and Michele Veeman. 1996. Model Choice and Structural Specification for Canadian Meat Consumption. *European Review of Agricultural Economics* 23, no. 3: 301-15.

Zhou, Xianming. 1991. "A Re-examination of Consistency as a Solution Concept in Oligopoly." Unpublished M.A. Thesis, University of New Brunswick.

Appendix I: Description and Sources of Data

Variables used in the empirical model and their data sources are presented below. All prices and income used are deflated by the CPI for all items for both Canada and the U.S. Variables are also presented in respective domestic currencies, unless if stated otherwise. The following indexing is used to define both the exogenous and endogenous variables: i = 1, 2, and 3 for western Canada, eastern Canada and the U.S. respectively. j = 12, 3 and 4 for Canada, U.S. and the rest of the world (ROW) respectively.

PCBDj - per capita beef disappearance in lbs/person; calculated from Livestock and Meat Trade Report data and AAFC electronic database for Canada. U.S data is sourced from the Economic Research Services (ERS) of the USDA.

RPBj - deflated retail beef price in cents/lbs from Statistics Canada for Canada and the USDA, ERS Red Meat Yearbook 2006 for the U.S.

RPPKj - deflated retail pork price in cents/lb from statistics Canada for Canada and the USDA, ERS Red Meat Yearbook 2006 for the U.S.

RPCKj - deflated retail chicken price in cents/lb from Statistics Canada for Canada and the US retail price for whole fryers from the Bureau of Labor Statistics, U.S. Department of Labor.

PCDj - deflated per capita disposable income in $/ person from Statistics Canada.

BPi - deflated by-product prices in cents/lbs calculated from data sourced from CANFAX, Canada Livestock and Meat Trade Report for Canada, and from The USDA, ERS historical price spread report for the U.S.

CPIj - consumer price index for all items from statistics Canada and U.S. Department of Labor for Canada and U.S., respectively.

ER - Canada- U.S. exchange rate in C$/US$ from Statistics Canada spot rate data.

CUj - industrial capacity utilization rate for food manufacturing industry data in % from Statistics Canada and the U.S. Federal Reserve statistics for both countries.

PCi - deflated price of cow in cents/lb carcass weight from Canada Livestock and Meat Trade Report and AAFC for Canada, and from the USDA, ERS historical price spread report for the U.S.

PHi - deflated price of heifer in cents/lb carcass weight from Canada Livestock and Meat Trade Report and AAFC for Canada, and from the USDA, ERS historical price spread report for the U.S.

PSi - deflated price of steer in cents/lb carcass weight from Canada Livestock and Meat Trade Report and AAFC for Canada, and from the USDA, ERS historical price spread report for the U.S.

PFCi - deflated price of feeder calf in $/lb, Med. No. 1, Oklahoma City, 500-550 lb for the U.S. from USDA, ERS Red Meat Yearbook 2006, and western and eastern Canada prices of feeder calves from Calgary and Toronto respectively. All Canadian data is from Statistics Canada.

PFi - deflated price of feed in $/ tonne. Alberta non-board price of barley for western Canada; elevator corn price in Ontario for eastern Canada; and No. 2 yellow corn price in central Illinois for U.S.

CWSi - average carcass weight for steer in lbs/head from Canada Livestock and Meat Trade Report, CANFAX and AAFC; and USDA, ERS Red Meat Yearbook 2006.

CWHi - average carcass weight for heifer in lbs/head from Canada livestock and meat trade report, CANFAX and AAFC; and USDA, ERS Red Meat Yearbook 2006.

CWCi - average carcass weight for cow in lbs/head from Canada Livestock and Meat Trade Report, CANFAX and AAFC; and USDA, ERS Red Meat Yearbook 2006.

CWBi - average carcass weight for bulls in lbs/head from Canada Livestock and Meat Trade Report, CANFAX and AAFC; and USDA, ERS Red Meat Yearbook 2006.

ICi - closing inventory of cows in '000 head from statistics Canada and USDA, ERS Red Meat Yearbook 2006.

INVi - closing inventory of cows and bulls in '000 head from Statistics Canada and USDA, ERS Red Meat Yearbook 2006.

DHIi - closing inventory for dairy heifer in '000 head from Statistics Canada and USDA, ERS Red Meat Yearbook 2006.

CBSij - slaughter cow and bull supply in '000 head from CANFAX and AAFC, and USDA, ERS Red Meat Yearbook 2006. Derived by adding cow and bull slaughter to exports and subtracting imports from it.

SHSij - slaughter steer supply in '000 head from CANFAX and AAFC, and USDA, ERS Red Meat Yearbook 2006. Derived by adding steer and heifer slaughter to exports and subtracting imports from it.

QBij - beef production in '000000 lbs, which is derived by multiplying total cattle slaughter by their respective carcass weights.

NTBi3 - net beef trade from western and eastern Canada to US in '000000 lbs, derived from subtracting total import from export .

NTBj4 - net beef trade with the rest of the world in '000000 lbs,

NTSCi3 - net cattle trade from western and eastern Canada to US in '000 head; derived from subtracting total fed and mature steer and heifer import from export .

NTCj4 - net cattle trade to the rest of the world in '000 head; derived from subtracting total fed and mature cattle import from export.

NTBCi3 - net bull and cow trade from western and eastern Canada to US in '000 head; derived from subtracting total fed and mature bull and cow import from export.

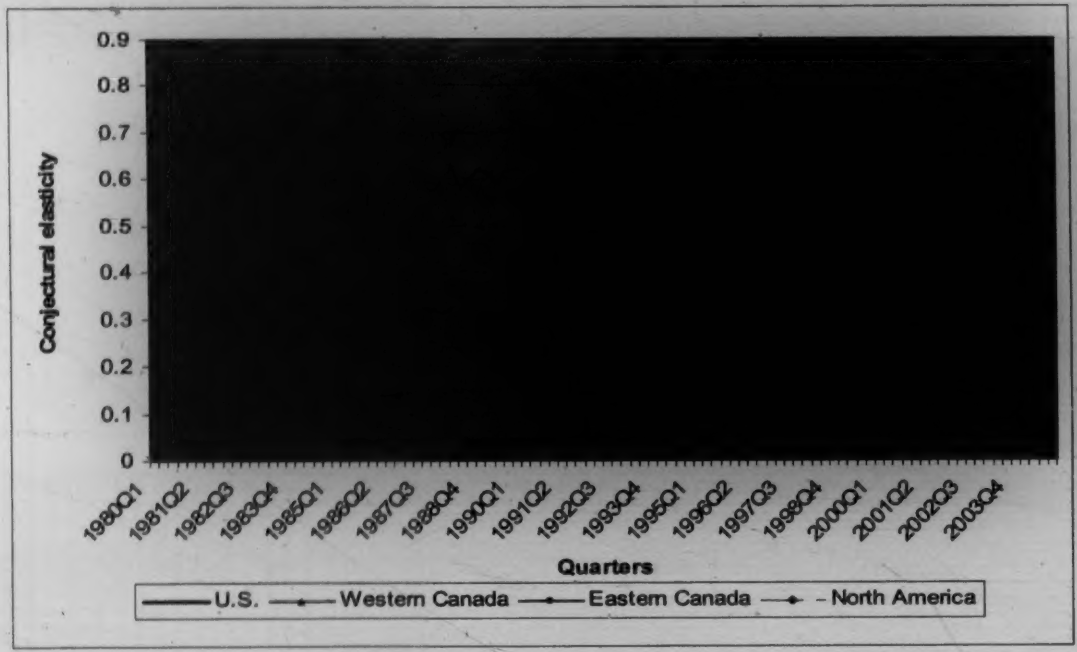
WLi - deflated labour rate for the regional meat packing and processing industries in $/month; derived by dividing total production wage bill by total production hours worked. Sourced from U.S. Department of Commerce Census of Manufactures, industry # 2011 (SIC code, meat packing plants) from 1980-1996 and NAIC code 3116 (meat slaughtering and processing) from 1997-2005 for the US; and Statistics Canada survey of employment, payrolls and hours; SIC 101-meat and poultry products industry (1980-1990) and Cat. # 72-002-XIB, employment, earnings and hours, NAIC code 3116 meat product manufacturing.

WKj - prime bank interest rate in % from the Bank of Canada monthly review and CANSIM.

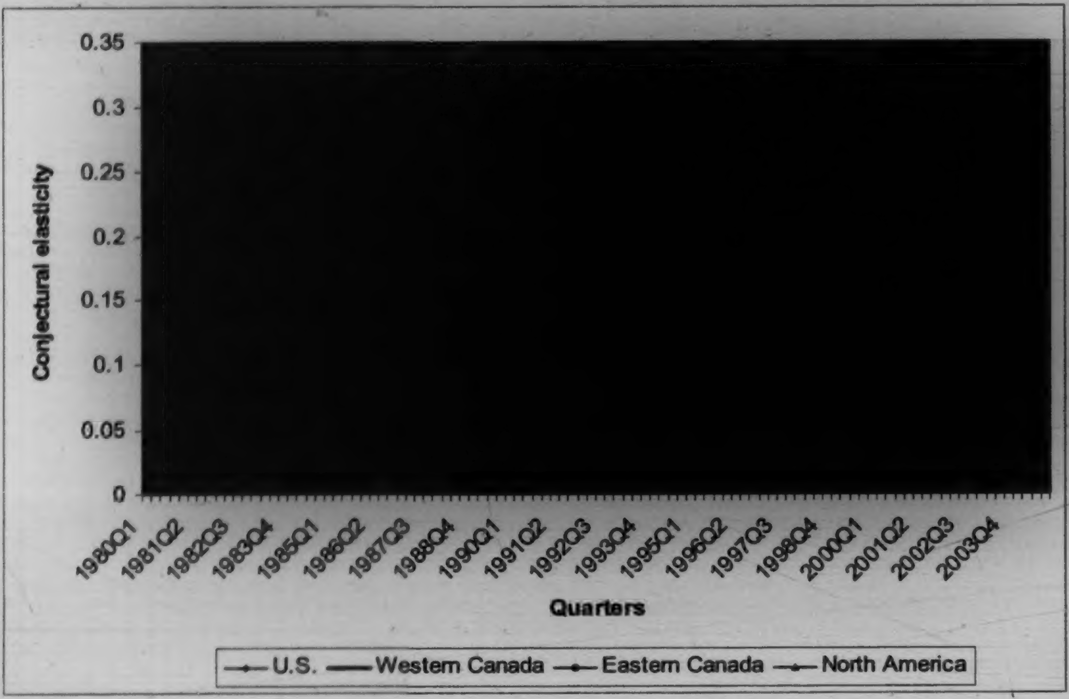
DLj - demand for labour in man-hour/month in meat packing and processing industry; sourced from U.S. Department of Commerce Census of Manufactures, industry # 2011(SIC code, meat packing plants) from 1980-1996 and NAIC code 3116(meat slaughtering and processing) from 1997-2005 for the US; and Statistics Canada survey of employment, payrolls and hours; SIC 101-meat and poultry products industry (1980-1990) and Cat. # 72-002-XIB, employment, earnings and hours, NAIC code 3116 meat product manufacturing.

DKj - demand for capital in million $; proxied by the cost of repair and capital expenditure for equipments, machinery, construction and building in meat product manufacturing NAIC # from Statistics Canada; and U.S. Department of Commerce Census of Manufactures, industry # 2011 (SIC code, meat packing plants) from 1980-1996 and NAIC code 3116 (meat slaughtering and processing) from 1997-2005.

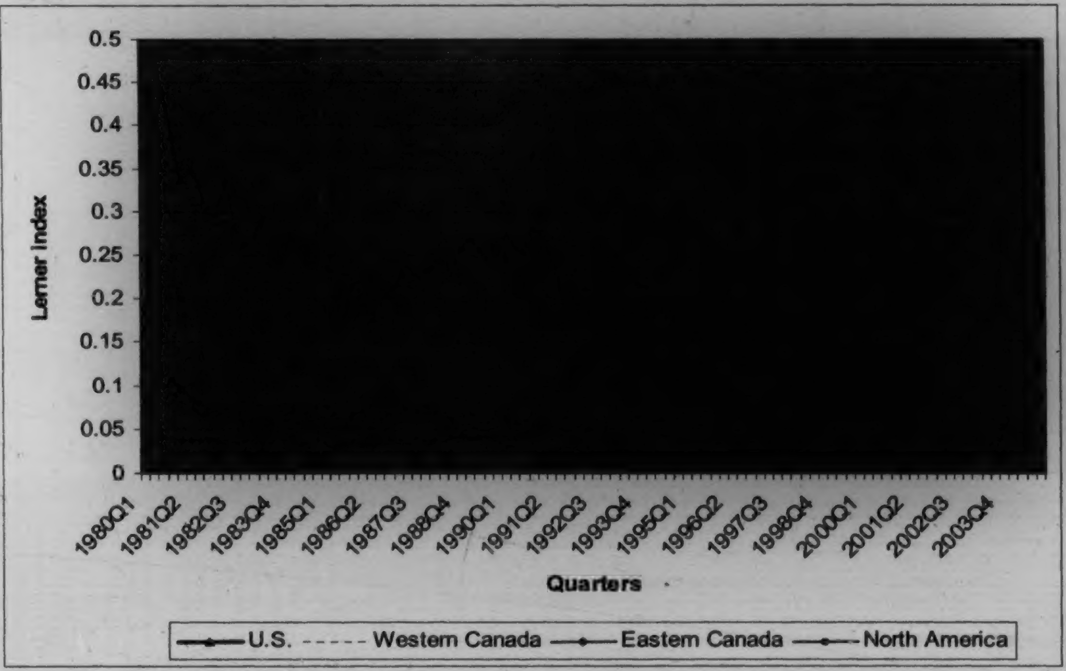
Appendix II: Quarterly Estimates of Oligopoly Conjectural Elasticities. 1980-2005



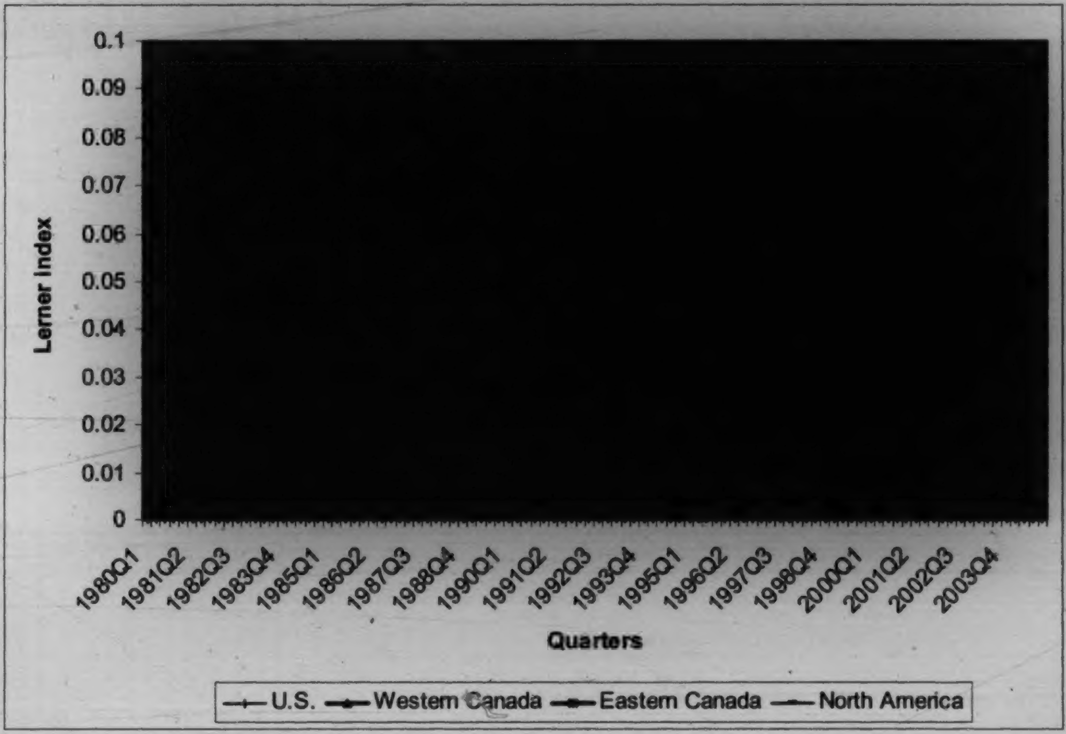
Appendix III: Quarterly Estimates of Oligopsony Conjectural Elasticities. 1980- 2005



Appendix IV: Quarterly Estimates of Oligopoly Lerner Indices. 1980-2005



Appendix V: Quarterly Estimates of Oligopsony Lerner indices.1980-2005



APPENDIX VI. Results of the Validation Statistics used to compare Actual and Simulated Values

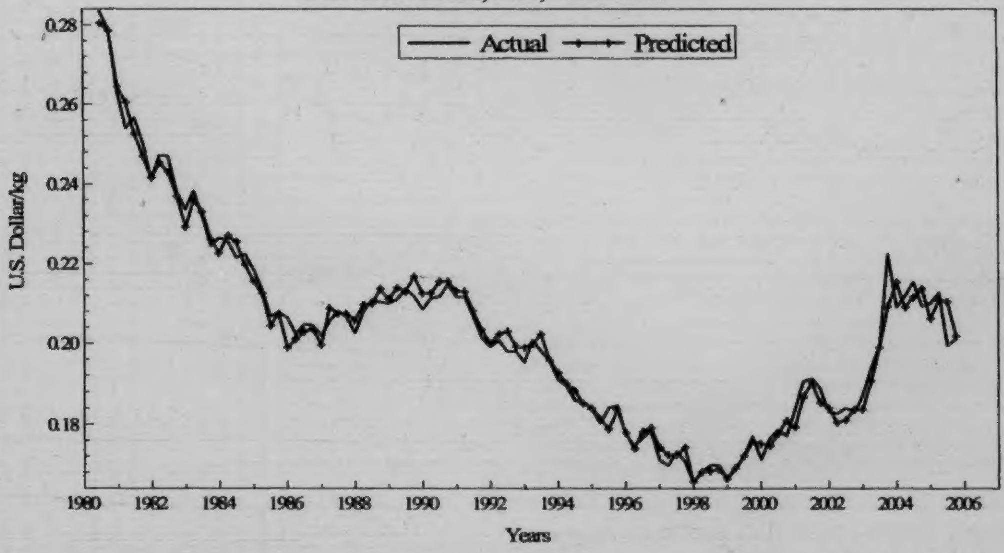
Variables	Correlation coefficient	R^2	% RMSE	Actual β vrs Predicted	T-test β =1	THEIL'S U Statistics	MSE Bias	MSE Variance	MSE Covariance
BD3	0.2598	0.0675	0.3180	0.1949	0.0000	0.3201	0.9333	0.0035	0.0631
BD12	0.6003	0.3604	0.0667	1.0382	0.7839	0.0663	0.0001	0.2779	0.7220
NTB123	0.2439	0.0595	5.3934	0.2068	0.0000	1.1358	0.0001	0.0177	0.9822
NTB34	-0.2566	0.0658	22.6437	-0.1342	0.0000	3.6040	0.7966	0.0300	0.1734
NTSC13	0.6251	0.3907	1.5731	0.6404	0.0000	0.5007	0.0105	0.0008	0.9887
NTBC13	0.2477	0.0614	0.8708	0.2963	0.0000	0.6868	0.0001	0.0210	0.9790
NTSC23	0.5478	0.3001	9.7751	0.4525	0.0000	0.9886	0.0005	0.0389	0.9606
NTBC23	0.0418	0.0017	18.2596	0.0196	0.0000	1.5887	0.0000	0.2389	0.7611
QB1	0.9864	0.9730	0.0479	0.9004	0.0000	0.0521	0.0247	0.2287	0.7466
QB12	0.9765	0.9535	0.0456	0.8739	0.0000	0.0471	0.0236	0.2031	0.7734
QB2	0.9171	0.8410	0.0510	1.0277	0.5382	0.0517	0.0094	0.0720	0.9186
QB3	0.1209	0.0146	0.1155	0.1002	0.0000	0.1135	0.0550	0.0186	0.9264
SHS3	0.2042	0.0417	0.0762	0.2136	0.0000	0.0737	0.0972	0.0011	0.9016
SHS1	0.9826	0.9654	0.0483	0.8896	0.0000	0.0496	0.0158	0.2173	0.7669
SHS2	0.9342	0.8727	0.0617	1.0299	0.4519	0.0642	0.0014	0.0673	0.9312
DUS	-0.2296	0.0527	0.0976	-0.1828	0.0000	0.0943	0.0527	0.0197	0.9276
DWS	0.9803	0.9610	0.0403	0.8947	0.0000	0.0422	0.0158	0.1722	0.8120
DES	0.9709	0.9426	0.0421	1.0992	0.0004	0.0453	0.0014	0.2091	0.7894
PSH1	0.5428	0.2946	0.3379	0.2681	0.0000	0.3047	0.0000	0.3619	0.6380
PSH2	0.6396	0.4091	0.2698	0.4089	0.0000	0.2396	0.0002	0.2202	0.7796
PCB1	0.8813	0.7767	0.3398	1.1327	0.0321	0.3371	0.8403	0.0336	0.1261
PCB2	0.5085	0.2586	2.4103	0.3657	0.0000	1.9418	0.9701	0.0030	0.0269
PBD12	0.8022	0.6434	0.0611	1.0052	0.9451	0.0578	0.0006	0.1143	0.8850
PFC1	0.5360	0.2873	0.2969	0.2832	0.0000	0.2765	0.0005	0.3120	0.6875
PFC2	0.6035	0.3642	0.2230	0.3981	0.0000	0.2144	0.0000	0.1814	0.8186
PFC3	-0.1139	0.0130	0.3752	-0.0572	0.0000	0.3608	0.0079	0.1799	0.8123
PCBD3	0.6207	0.3852	0.0947	0.3901	0.0000	0.0980	0.0003	0.2244	0.7753
PCBD12	0.8532	0.7280	0.0667	1.0158	0.8006	0.0623	0.0001	0.0941	0.9058

APPENDIX VI. CONT'D

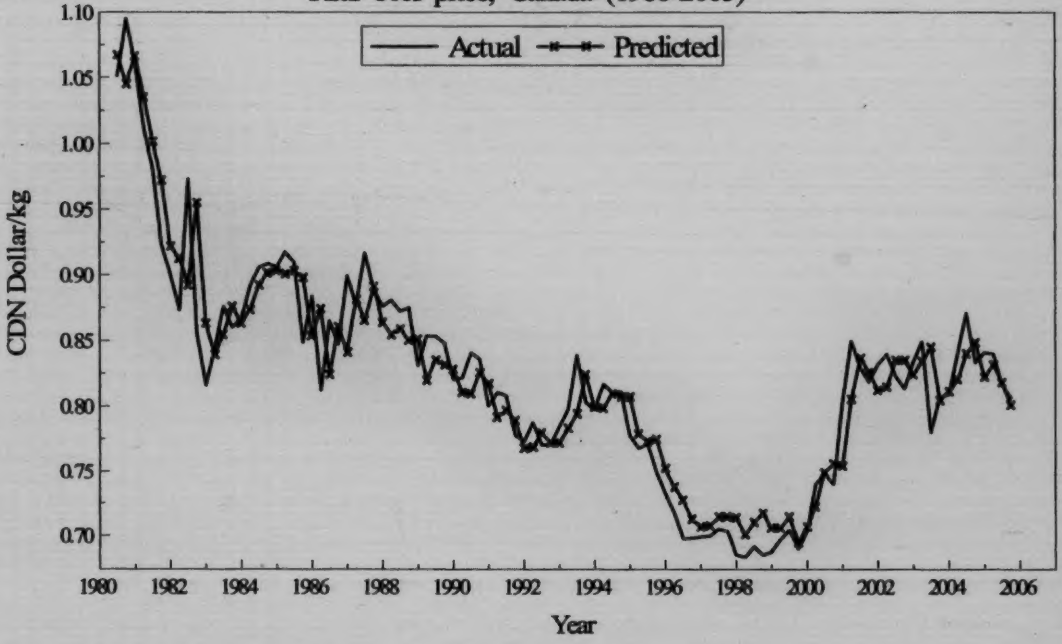
Variables	Correlation coefficient	R^2	% RMSE	Actual β vrs Predicted	T-test β =1	THEIL'S U Statistics	MSE Bias	MSE Variance	MSE Covariance
CBI3	0.1569	0.0246	0.1139	0.1087	0.0000	0.1104	0.3543	0.0484	0.5974
CB3	0.2517	0.0634	0.2190	0.1764	0.0000	0.2006	0.0067	0.0781	0.9152
CB2	0.6752	0.4559	0.2296	0.7390	0.0017	0.2121	0.0000	0.0124	0.9876
CB1	0.4480	0.2007	0.2651	0.7807	0.1645	0.2473	0.0001	0.2228	0.7772
SH3	0.1587	0.0252	0.0797	0.1571	0.0000	0.0771	0.0843	0.0001	0.9157
SH1	0.8949	0.8009	0.1027	0.9629	0.4445	0.0979	0.0276	0.0242	0.9481
SH2	0.8063	0.6501	0.0995	1.1269	0.1298	0.0938	0.0021	0.2255	0.7723
INV1	0.9371	0.8781	0.0756	0.9861	0.7067	0.0668	0.1608	0.0170	0.8223
INV2	0.3809	0.1451	0.0792	0.7697	0.2230	0.0815	0.0030	0.2931	0.7039
CWS1	0.9713	0.9435	0.0206	1.0062	0.8015	0.0203	0.0005	0.0213	0.9782
CWS2	0.9638	0.9289	0.0245	1.0064	0.8197	0.0241	0.0014	0.0251	0.9735
CWS3	0.5585	0.3120	0.0524	0.5182	0.0000	0.0520	0.0123	0.0063	0.9815
CWH1	0.9793	0.9590	0.0268	1.0171	0.4211	0.0270	0.0000	0.0334	0.9665
CWH2	0.9692	0.9393	0.0245	1.0275	0.2968	0.0258	0.0000	0.0526	0.9474
CWH3	0.9120	0.8317	0.0298	1.0669	0.1684	0.0287	0.0022	0.1227	0.8752
CWC1	0.9362	0.8765	0.0326	1.0117	0.7599	0.0338	0.0006	0.0450	0.9544
CWC2	0.6829	0.4663	0.0570	0.9743	0.8064	0.0605	0.0010	0.1673	0.8317
CWC3	0.9542	0.9104	0.0192	0.9605	0.1955	0.0188	0.0002	0.0005	0.9994
PBF3	0.3708	0.1375	0.3134	0.1235	0.0000	0.3207	0.0002	0.5146	0.4852
PS1	0.5546	0.3075	0.3387	0.2766	0.0000	0.3052	0.0000	0.3612	0.6388
PS2	0.6417	0.4118	0.2602	0.4121	0.0000	0.2321	0.0002	0.2177	0.7821
PS3	0.2969	0.0882	0.3646	0.1792	0.0000	0.3289	0.0073	0.1552	0.8376
PSH3	0.2699	0.0729	0.3502	0.1632	0.0000	0.3193	0.0071	0.1495	0.8434
PSCB3	0.2751	0.0757	0.7970	0.8002	0.4790	0.8071	0.9400	0.0278	0.0322
CBS3	0.2292	0.0525	0.2268	0.1541	0.0000	0.2080	0.0058	0.0933	0.9009

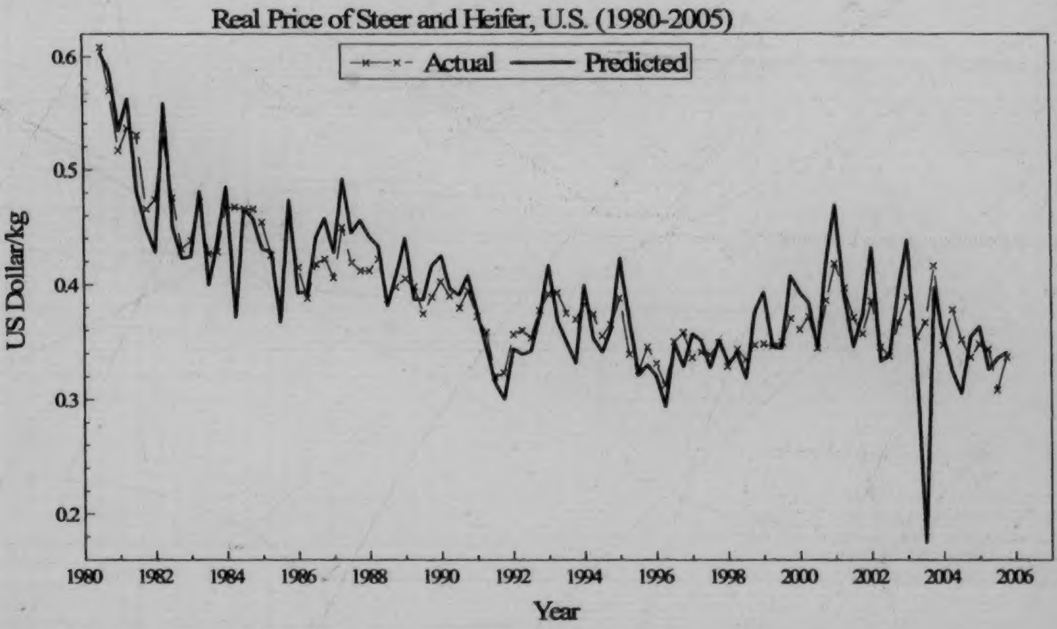
Appendix VII: Model Simulation Graphs.

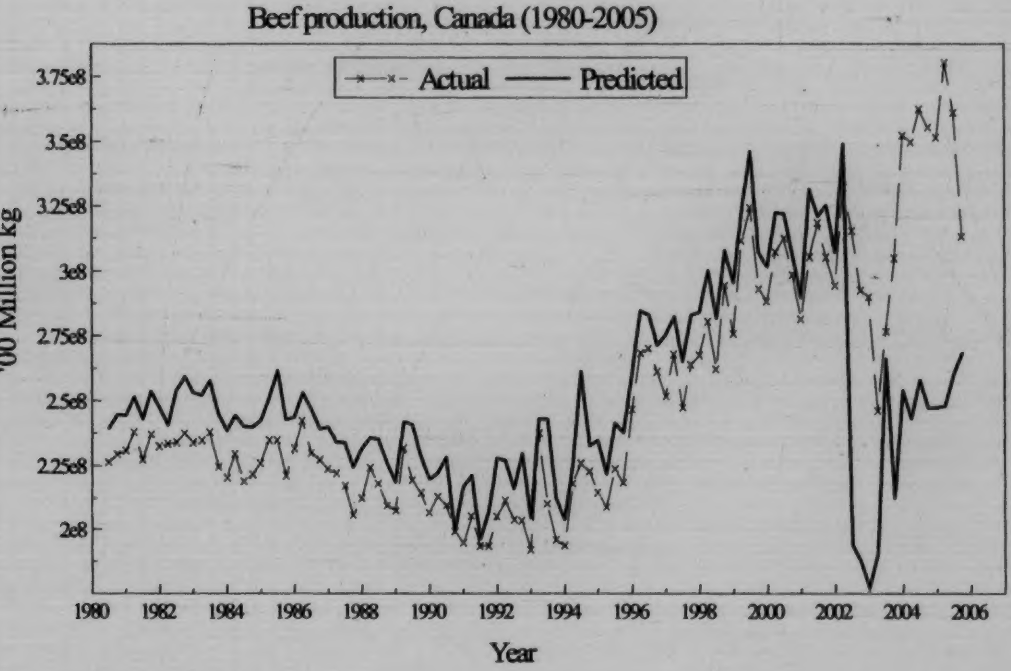
Real Price of Beef, U.S., 1980-2004.



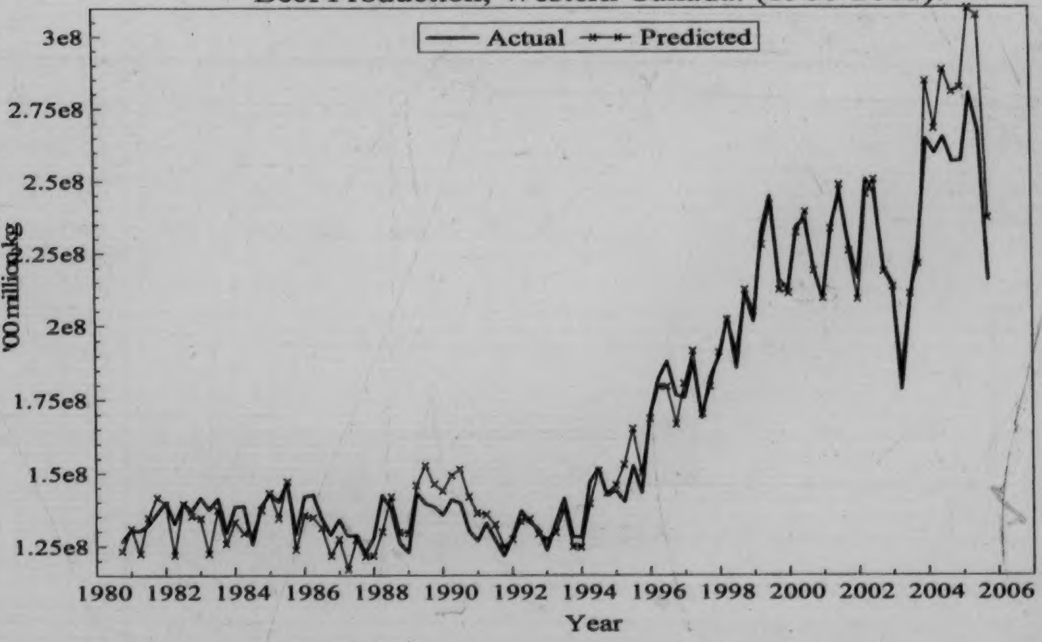
Real beef price, Canada (1980-2005)



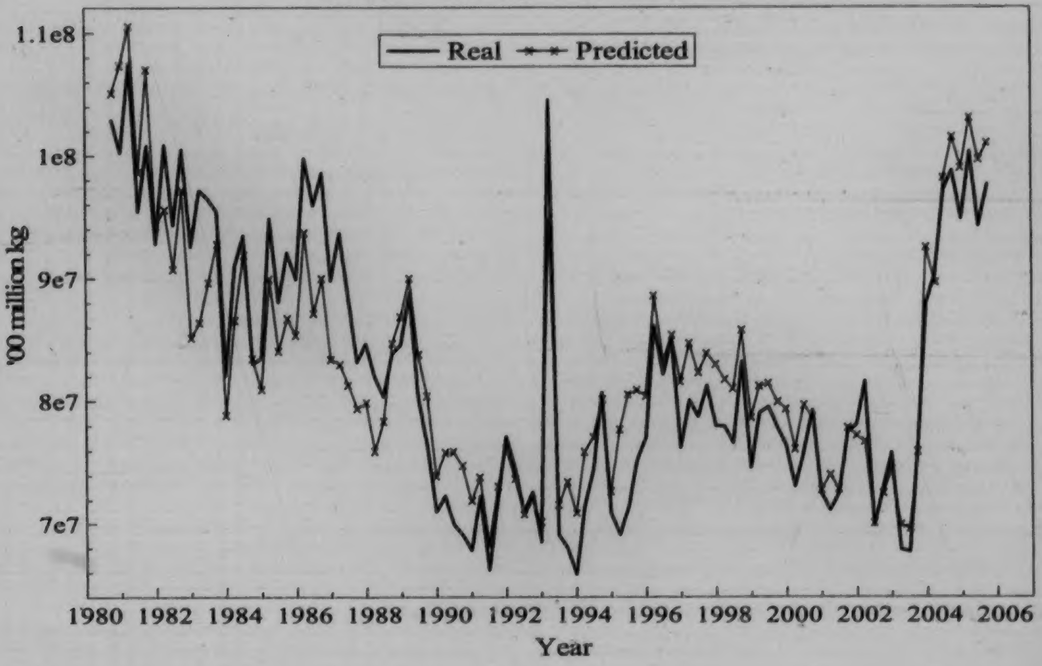

Real Price of Steer and Heifer, U.S. (1980-2005)
Actual
Predicted
US Dollar/kg
0.6
0.5
0.4
0.3
0.2
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

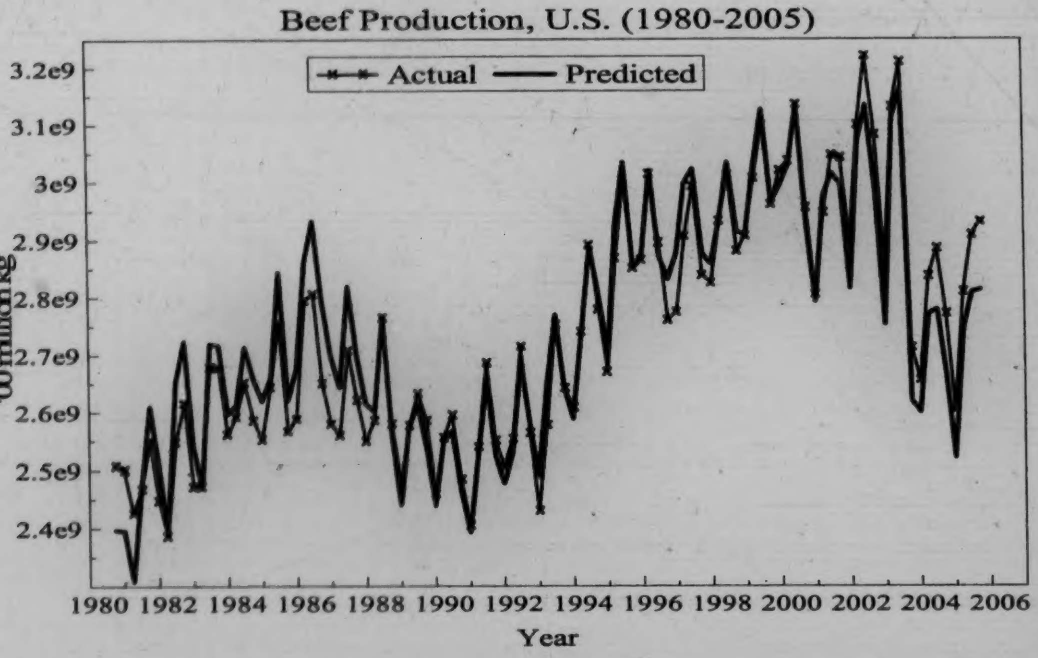

Beef production, Canada (1980-2005)
Actual
Predicted
'00 Million kg
3.75e8
3.5e8
3.25e8
3e8
2.75e8
2.5e8
2.25e8
2e8
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

Beef Production, Western Canada. (1980-2005).

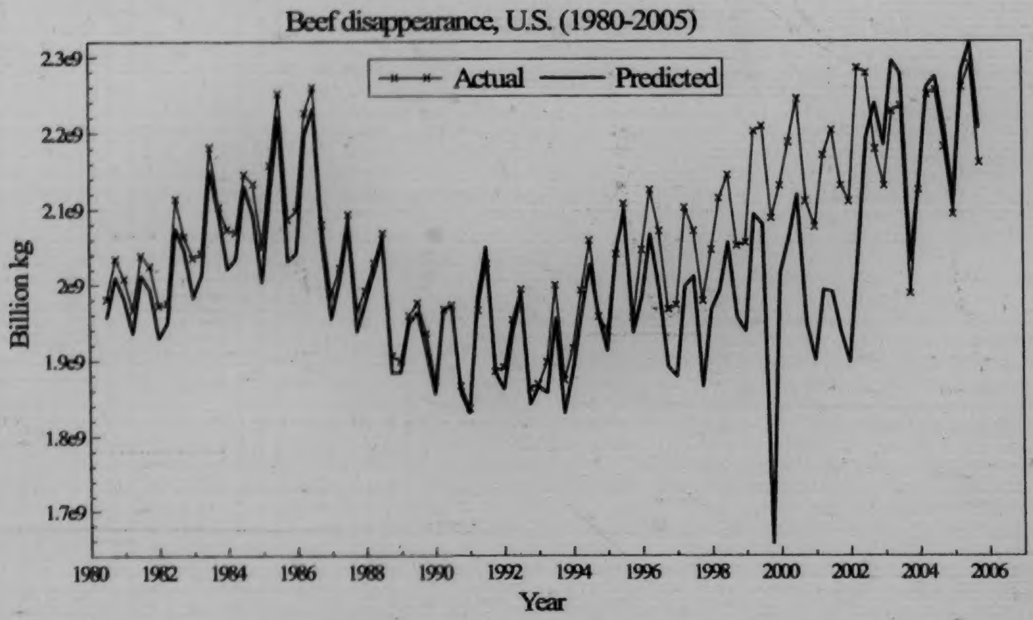


Beef Production, eastern Canada. (1980-2005)

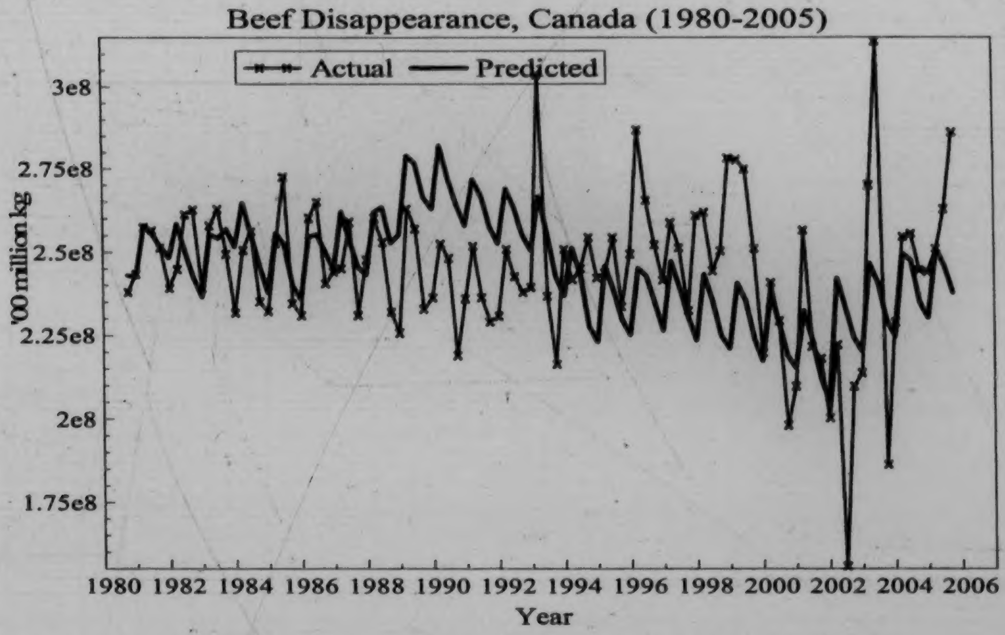


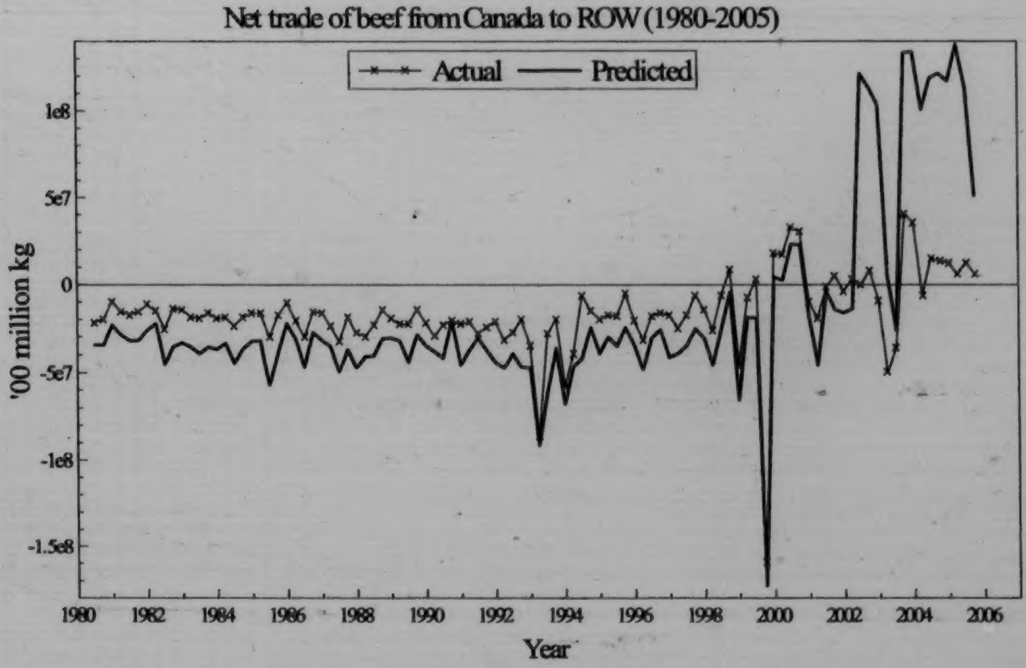


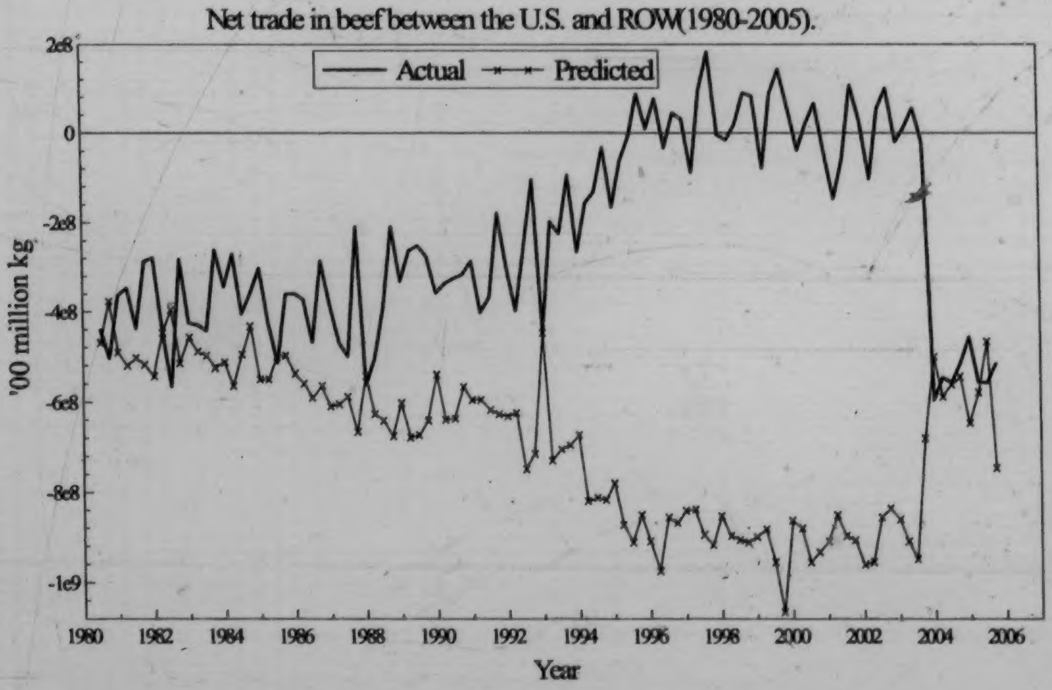
Beef Production, U.S. (1980-2005)

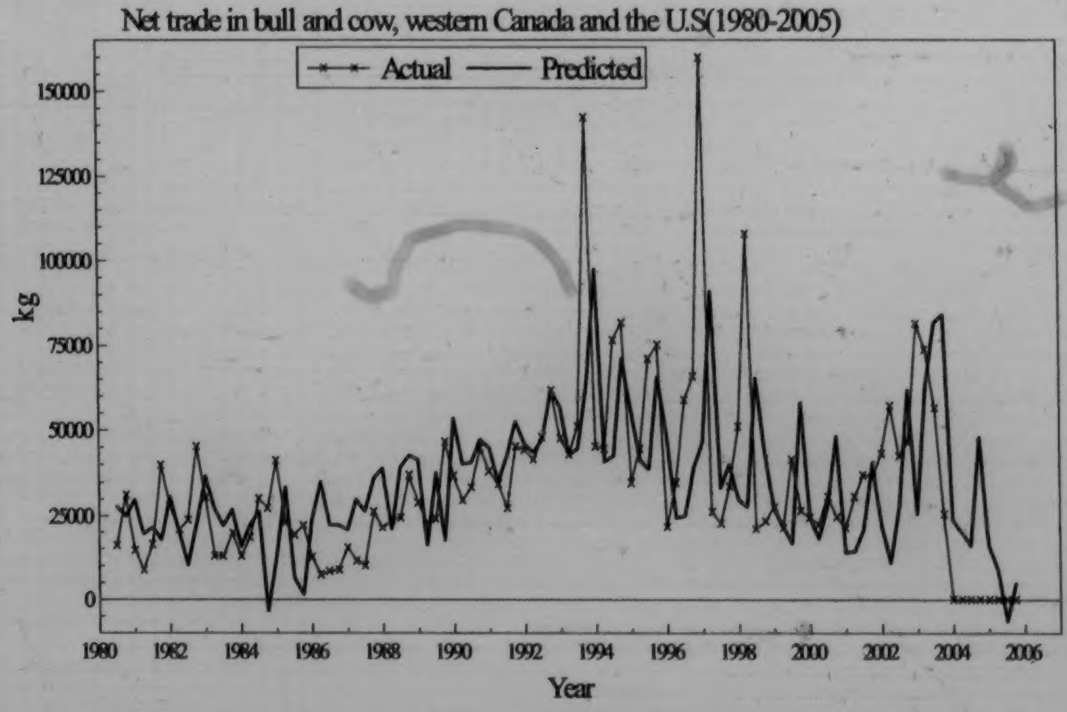


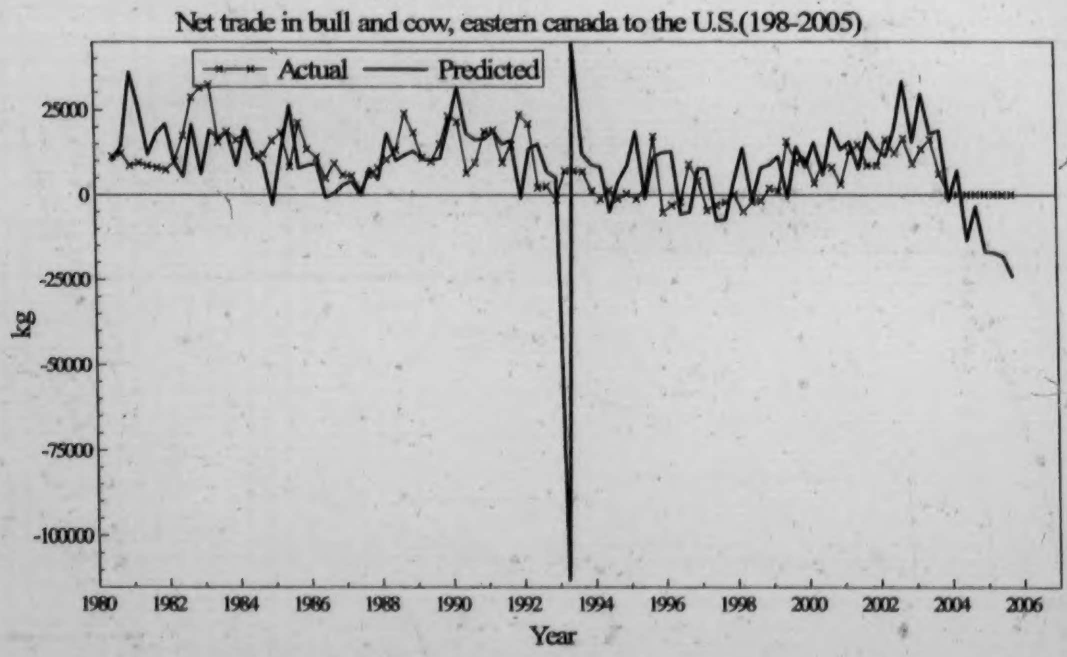
Beef disappearance, U.S. (1980-2005)


Beef Disappearance, Canada (1980-2005)

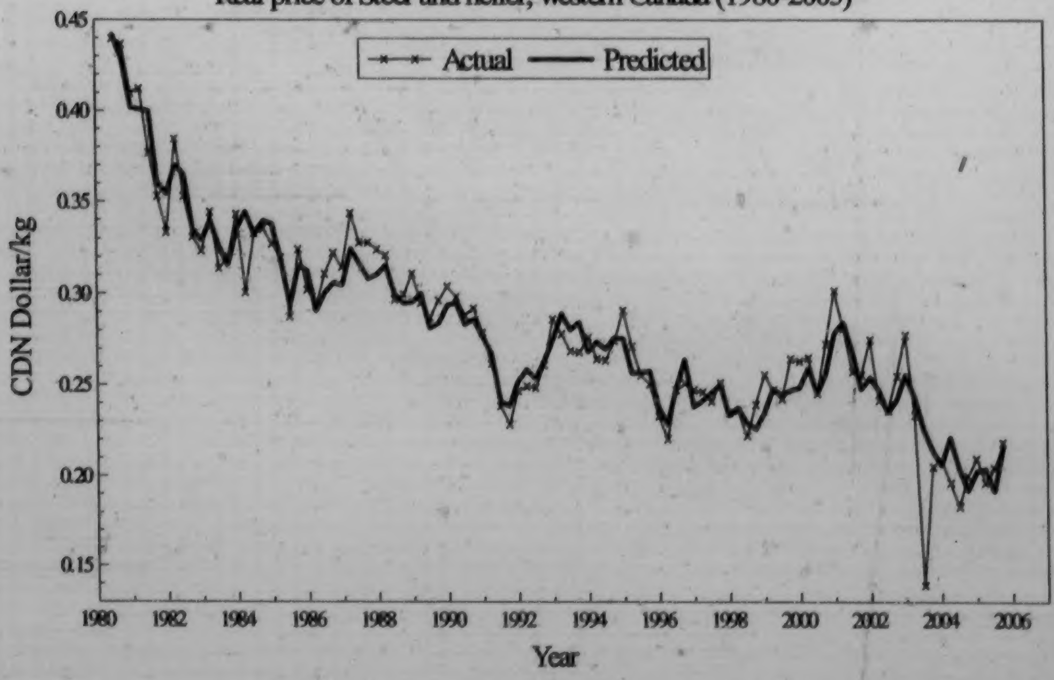

Net trade of beef from Canada to ROW (1980-2005)


Net trade in beef between the U.S. and ROW(1980-2005).


Net trade in bull and cow, western Canada and the U.S(1980-2005)

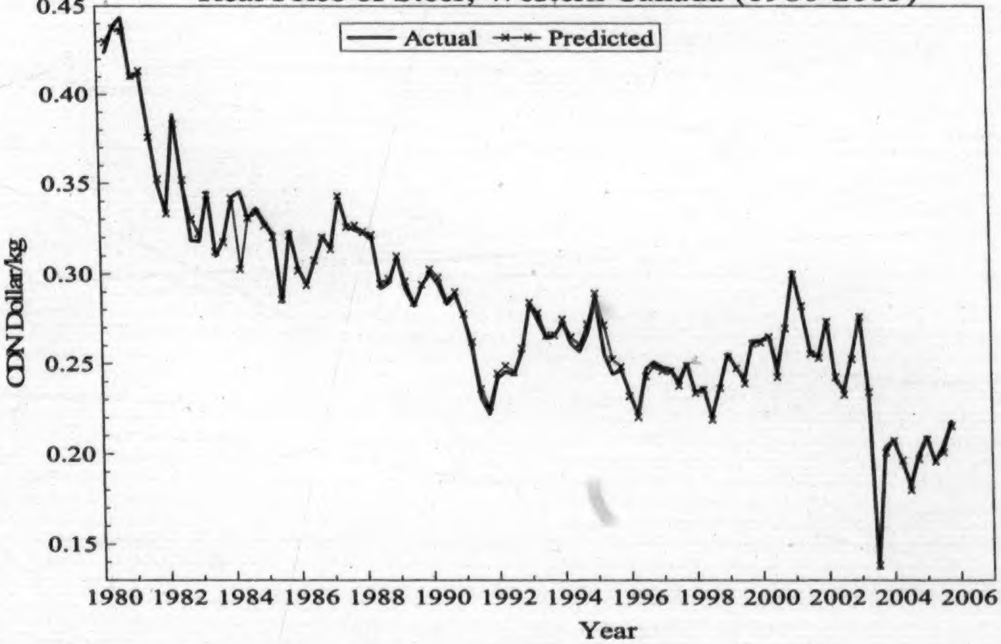


Net trade in bull and cow, eastern canada to the U.S.(198-2005)

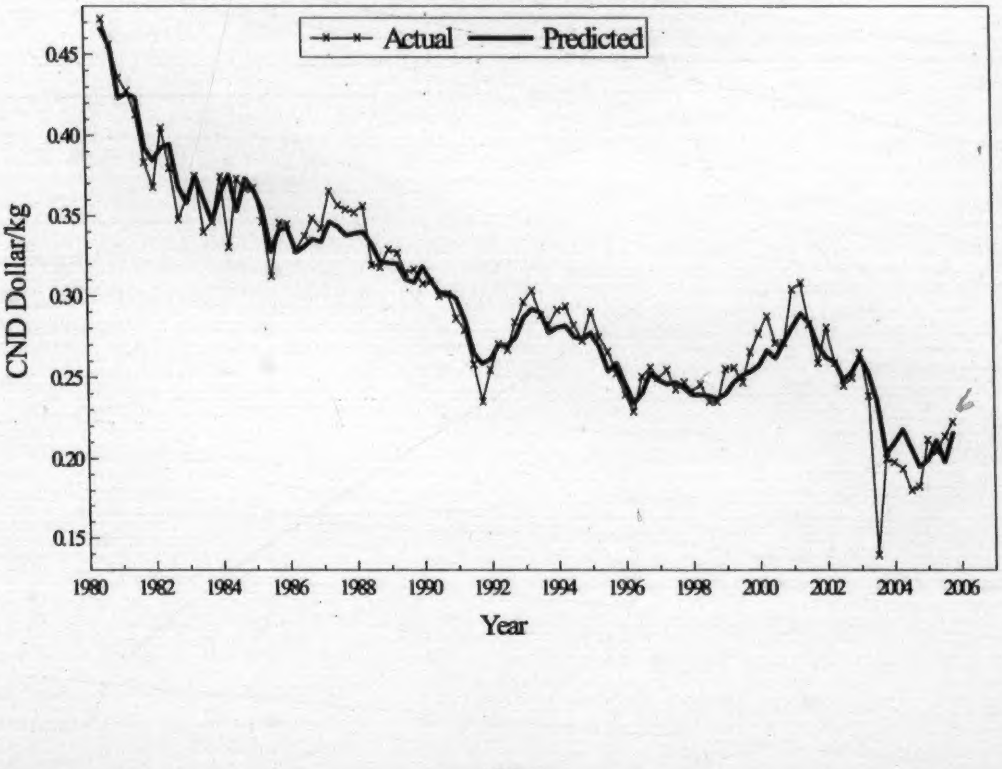


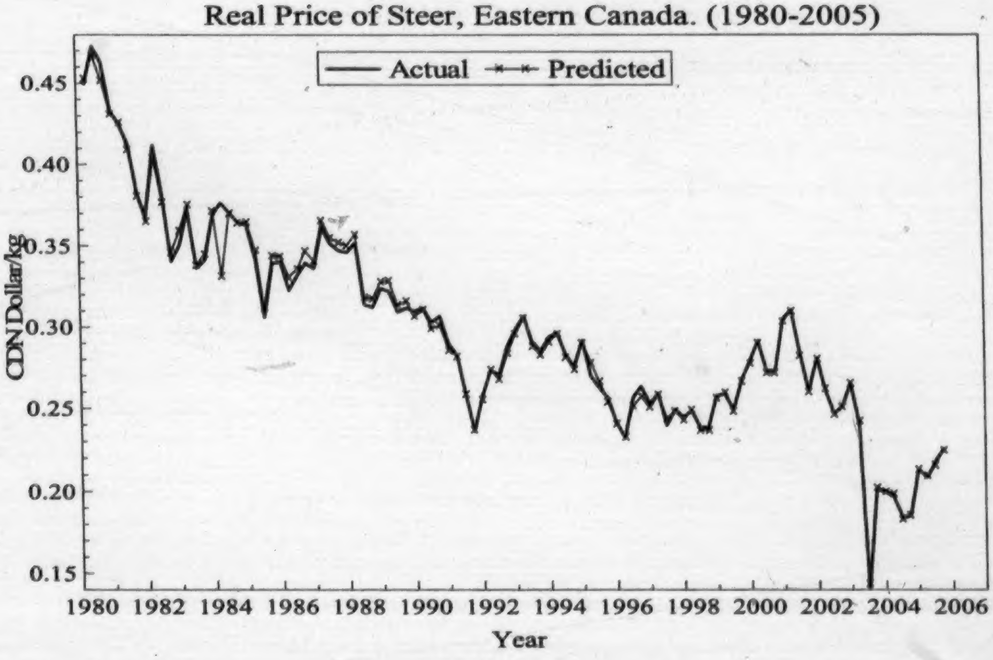
Real price of Steer and heifer, western Canada (1980-2005)

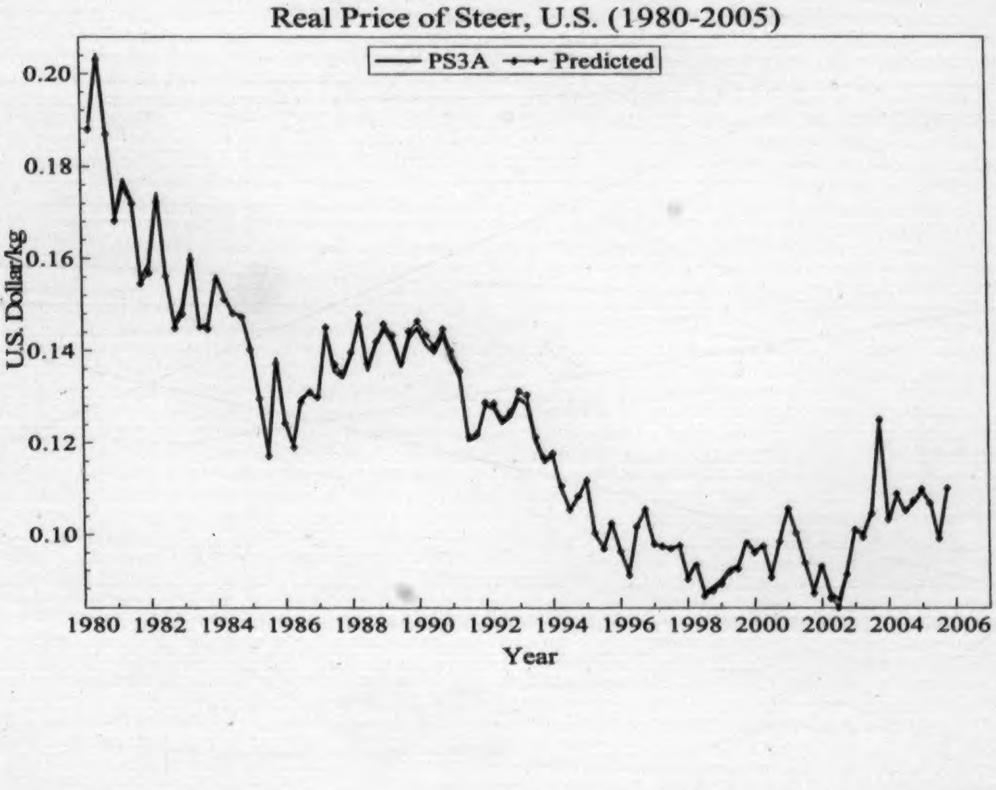
Real Price of Steer, Western Canada (1980-2005)

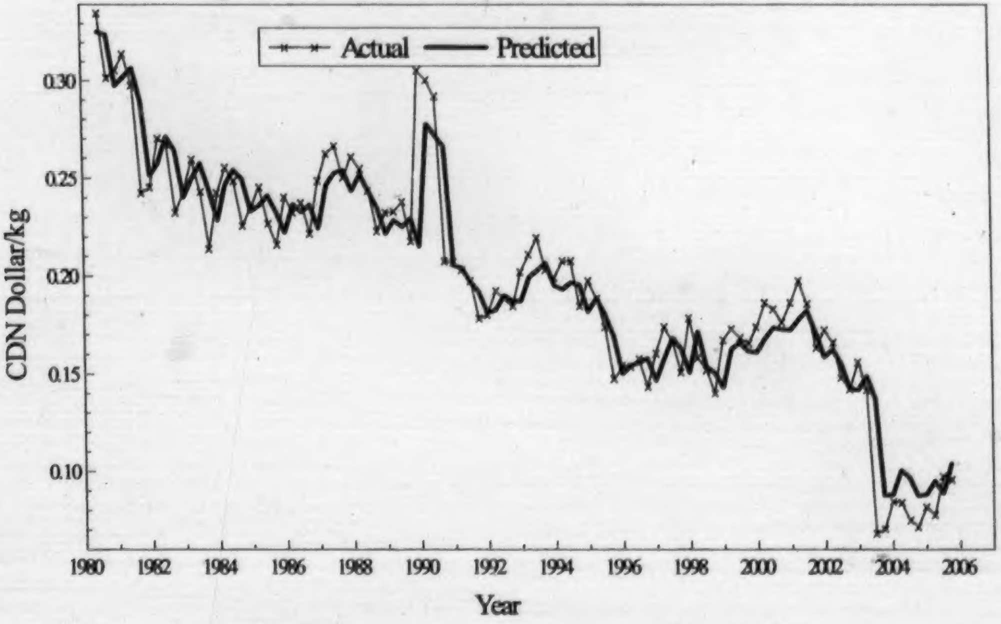


Real price of steer and heifer, eastern Canada (1980-2005)

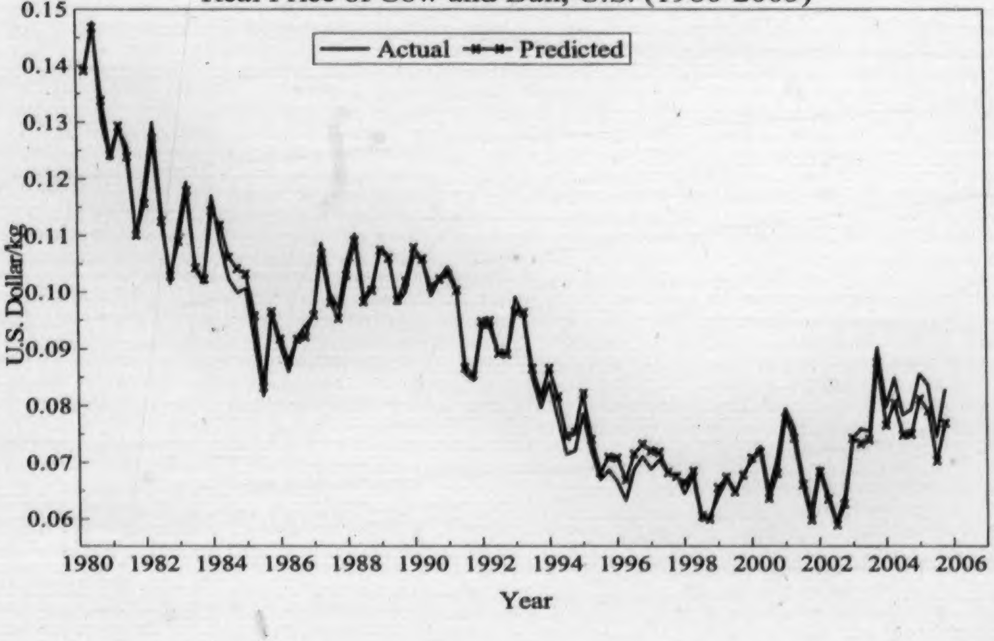



Real Price of Steer, Eastern Canada. (1980-2005)
Actual
Predicted
CDN Dollar/kg
0.45
0.40
0.35
0.30
0.25
0.20
0.15
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year

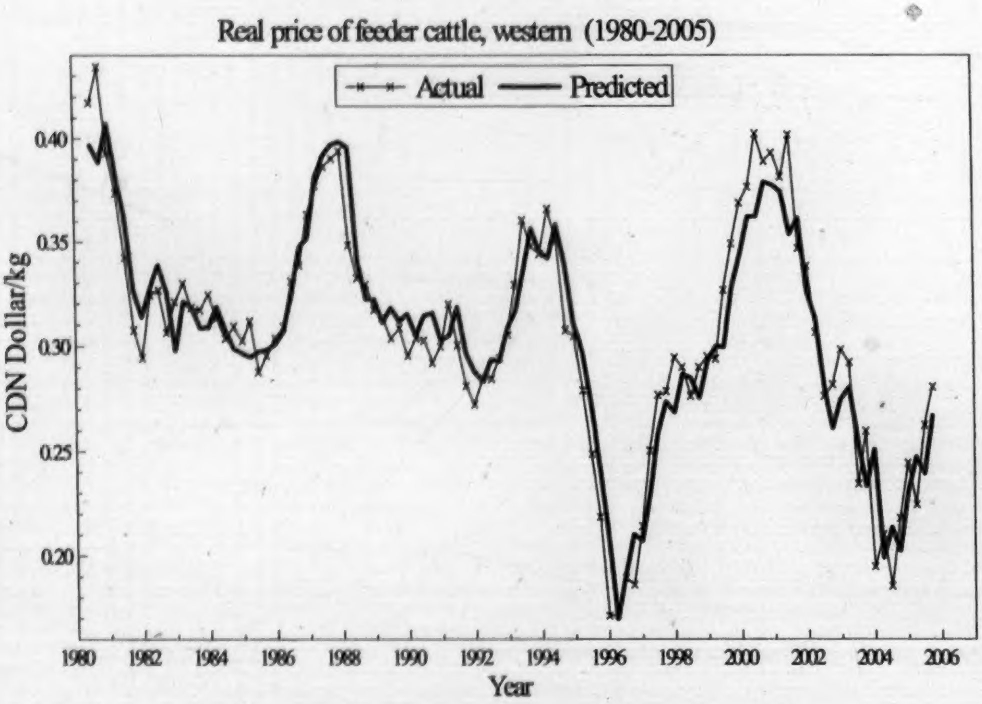

Real Price of Steer, U.S. (1980-2005)
PS3A
Predicted
U.S. Dollar/kg
0.20
0.18
0.16
0.14
0.12
0.10
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year



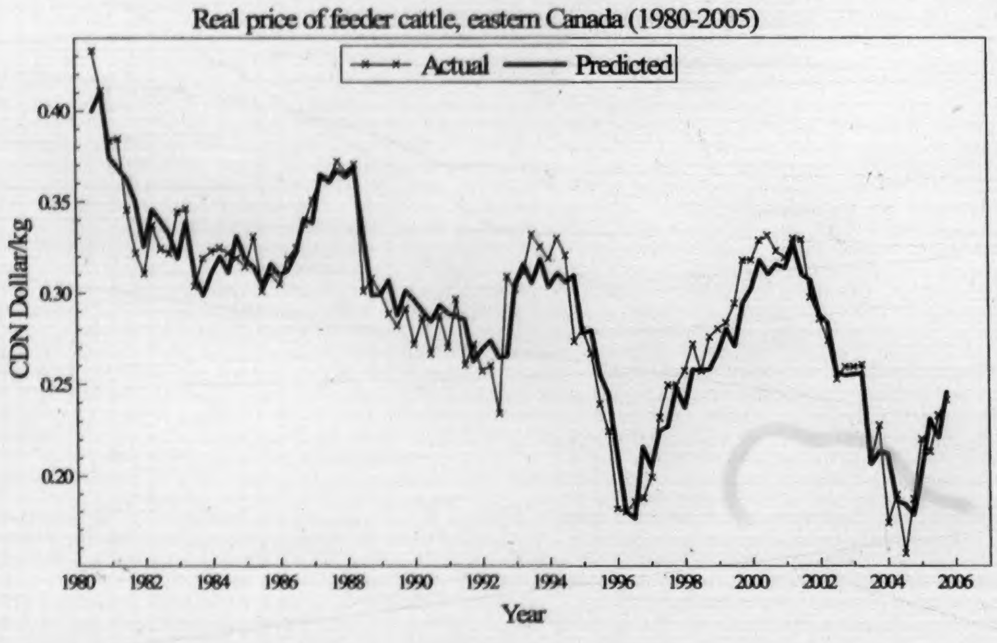
Real price of cow and bull, Western Canada (1980-2005)



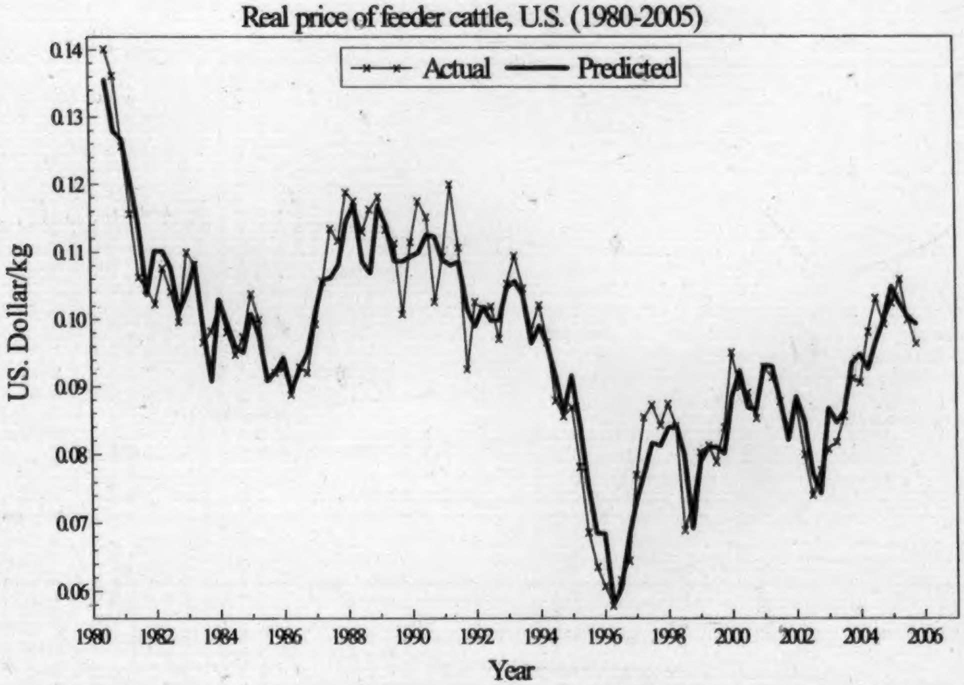
Real Price of Cow and Bull, U.S. (1980-2005)

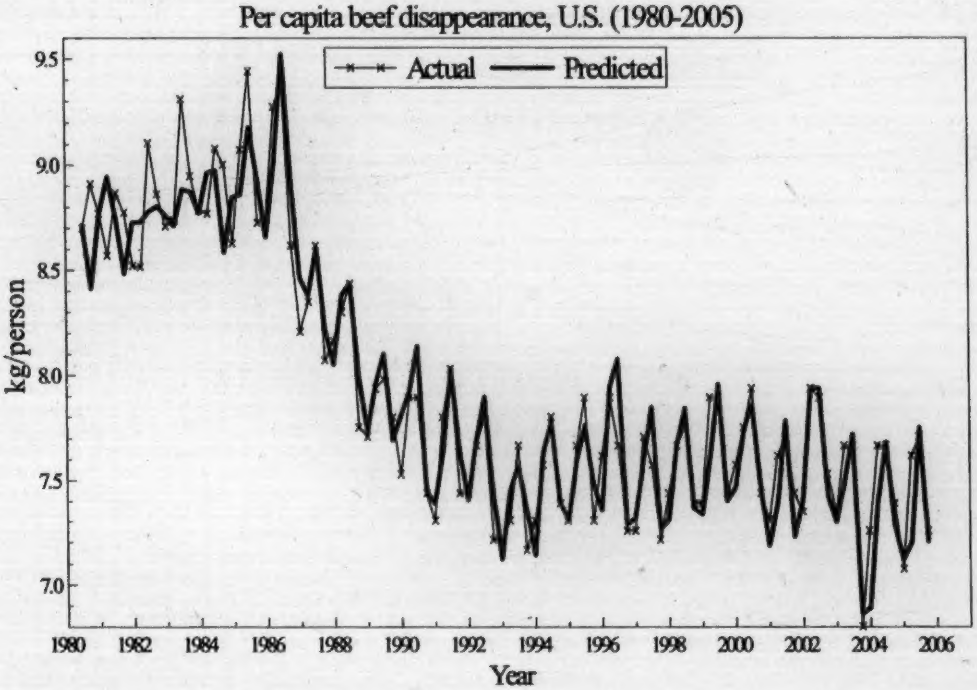


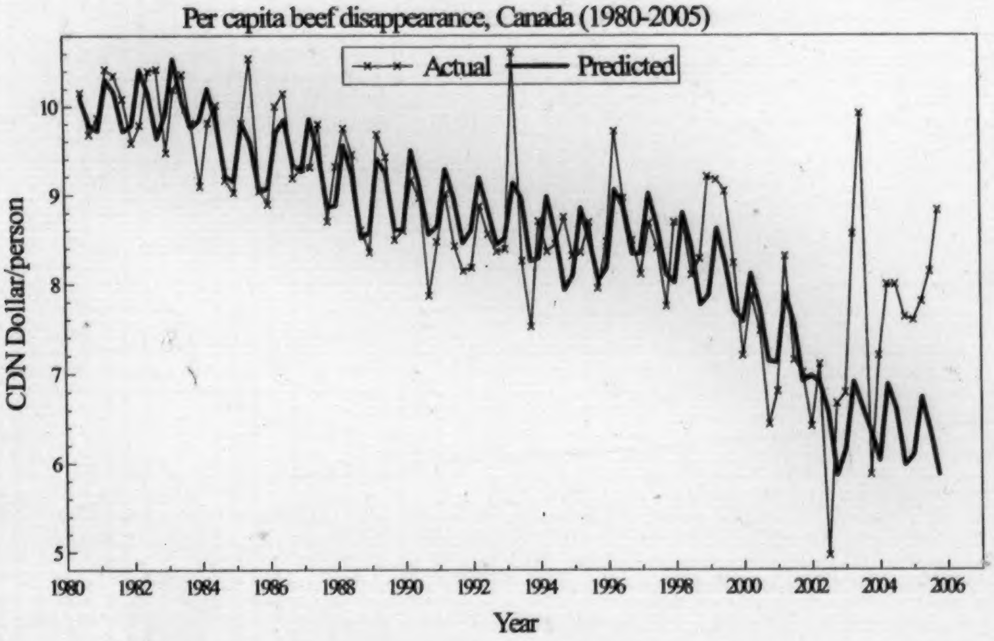
Real price of feeder cattle, western (1980-2005)



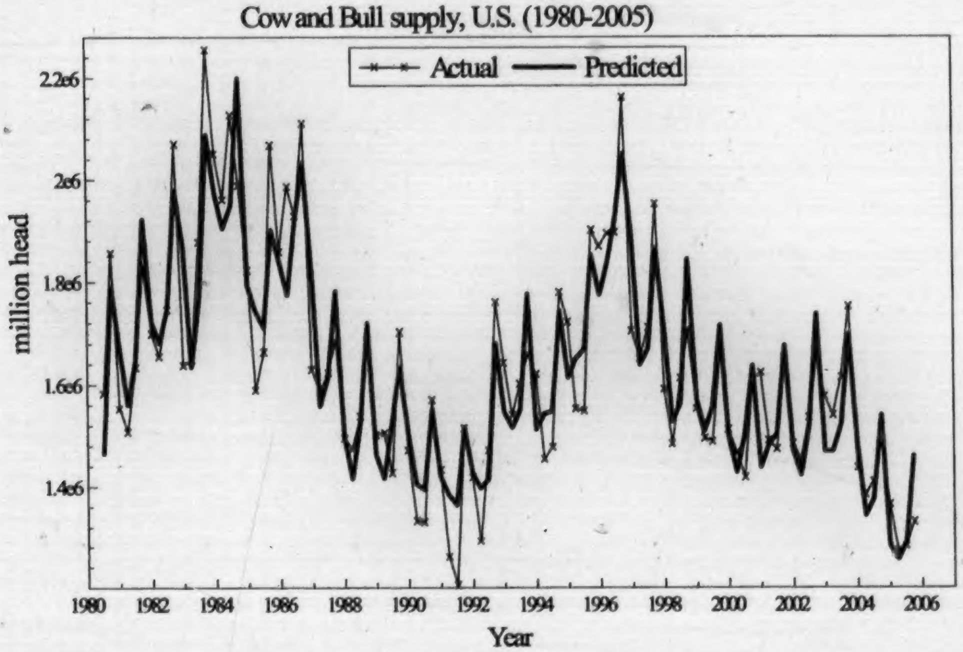
Real price of feeder cattle, eastern Canada (1980-2005)


Real price of feeder cattle, U.S. (1980-2005)
Actual
Predicted
US. Dollar/kg
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

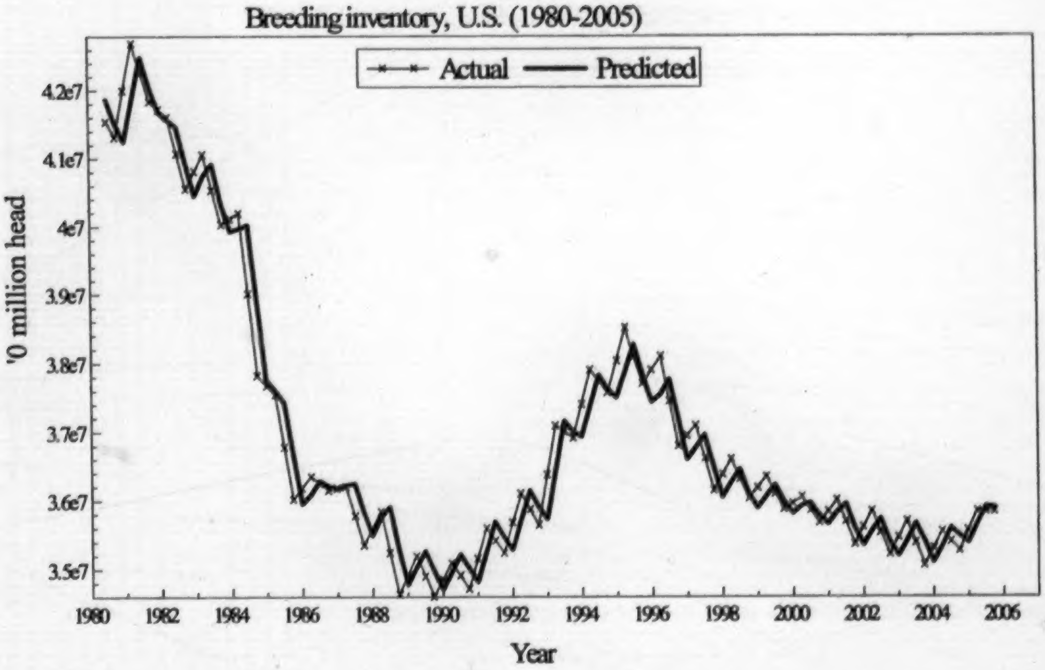

Per capita beef disappearance, U.S. (1980-2005)
Actual
Predicted
kg/person
9.5
9.0
8.5
8.0
7.5
7.0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

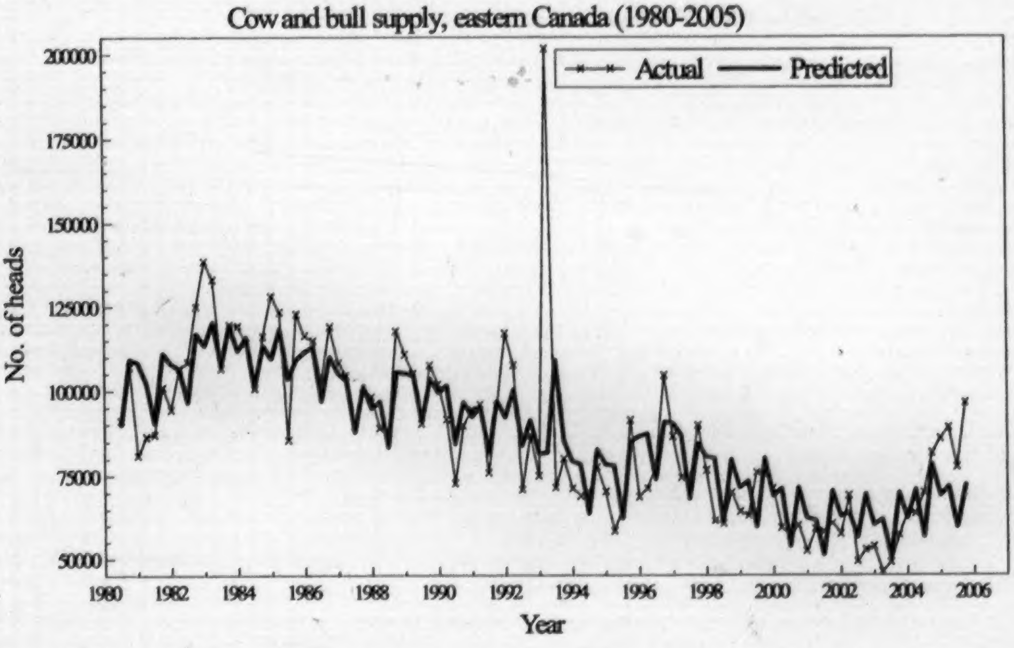


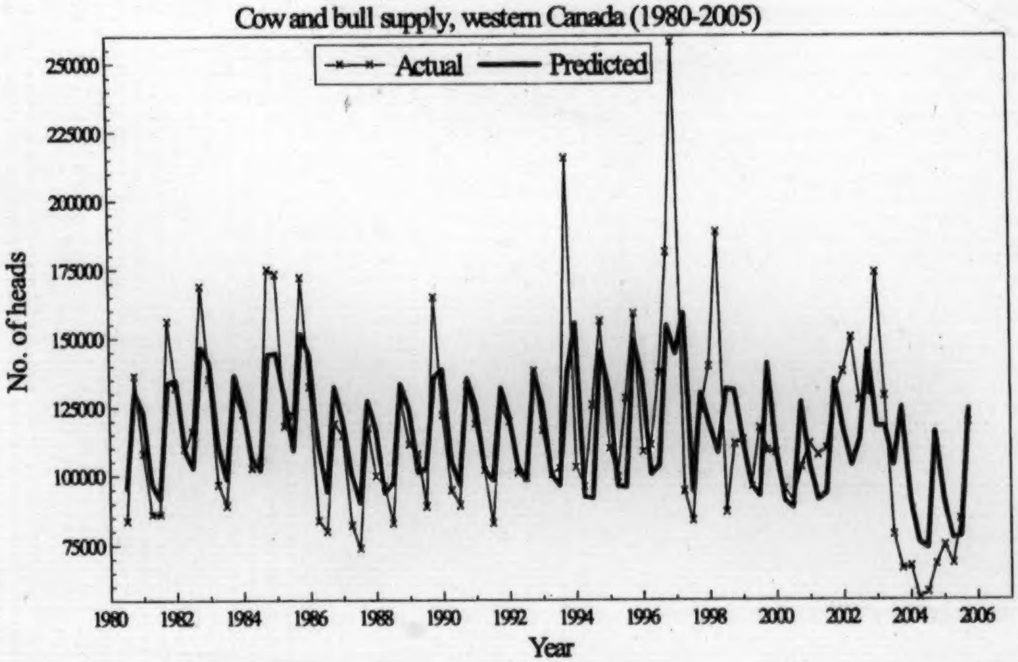
Per capita beef disappearance, Canada (1980-2005)

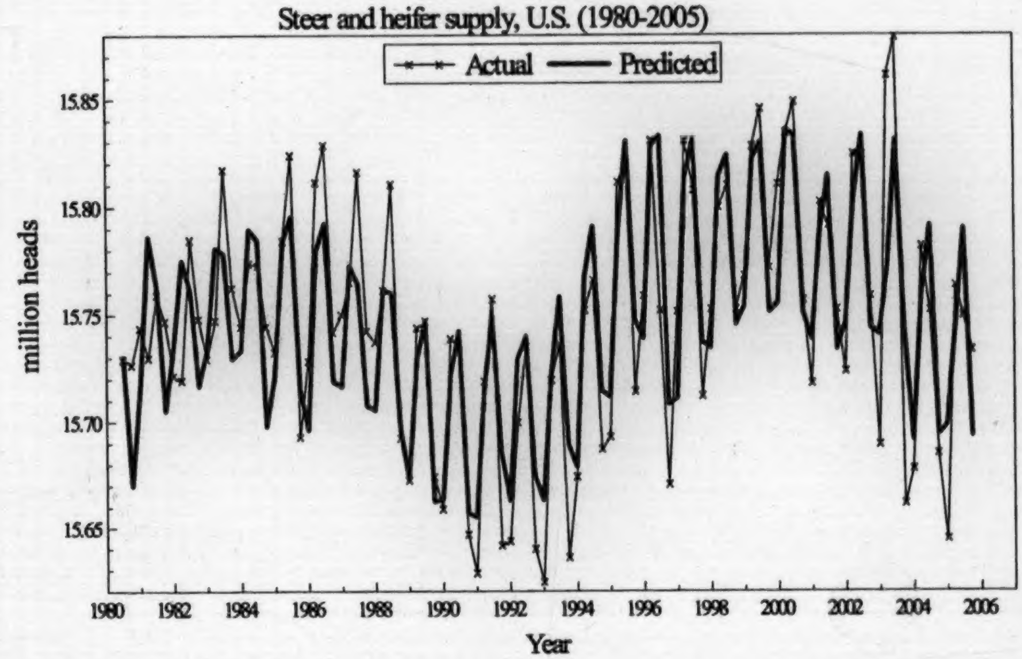


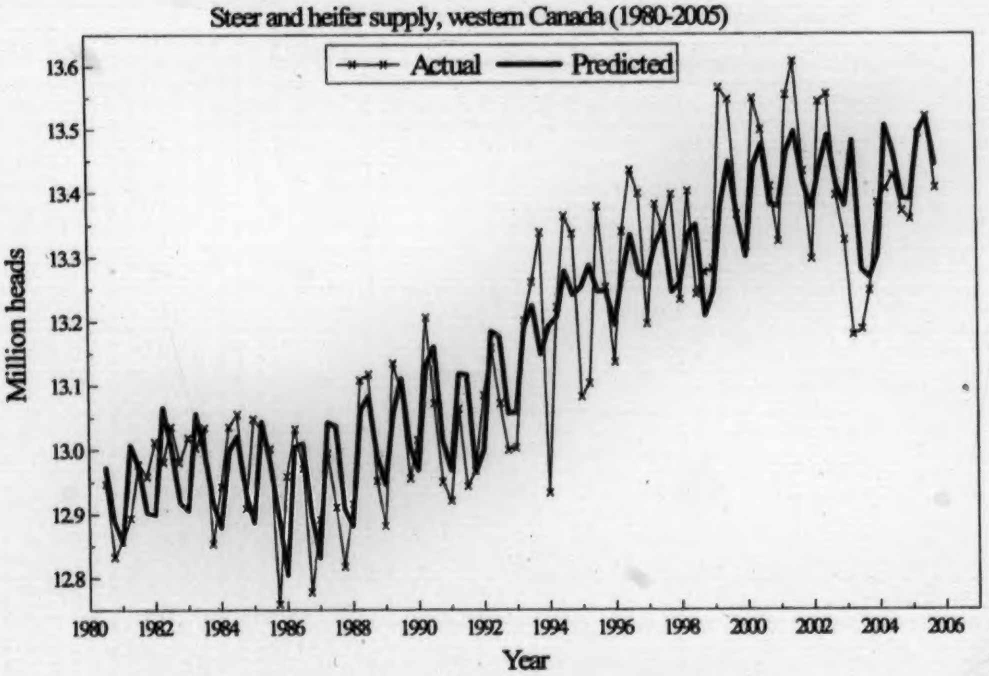
Cow and Bull supply, U.S. (1980-2005)

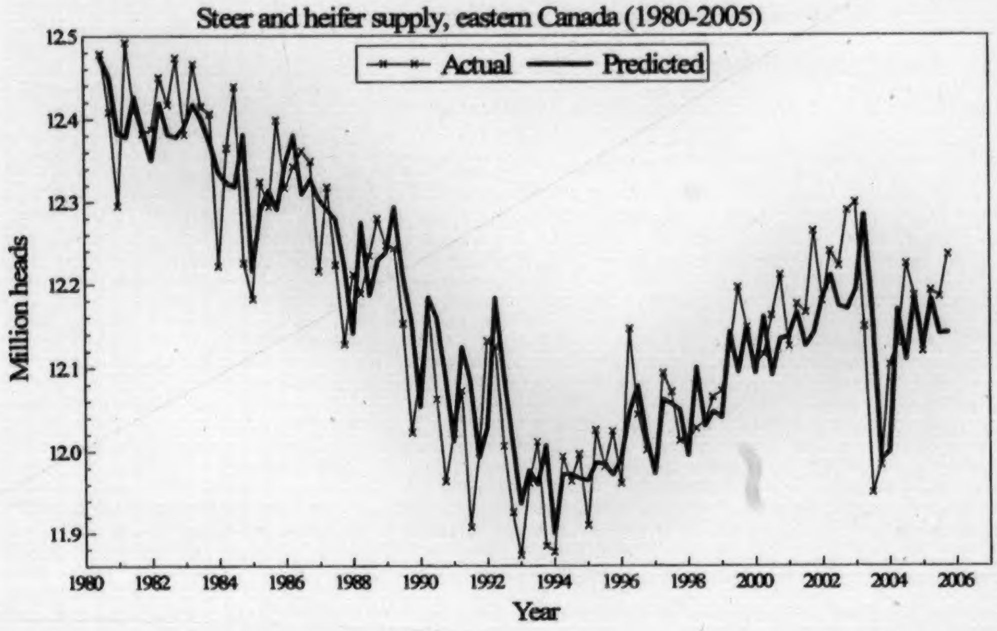

Breeding inventory, U.S. (1980-2005)
Actual
Predicted
'0 million head
4.2e7
4.1e7
4e7
3.9e7
3.8e7
3.7e7
3.6e7
3.5e7
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

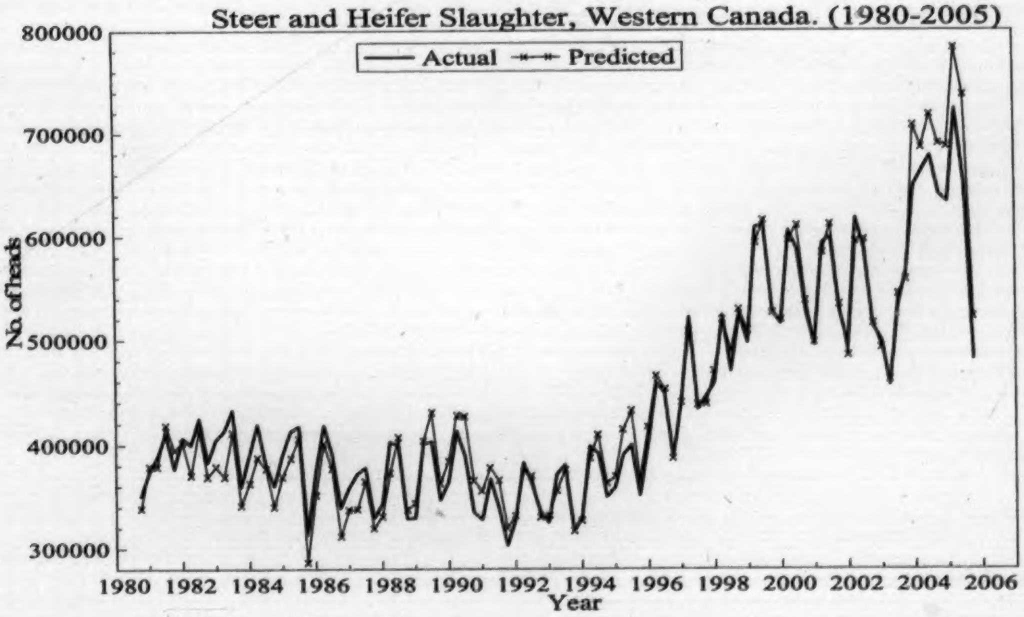

Cow and bull supply, eastern Canada (1980-2005)
Actual
Predicted
No. of heads
200000
175000
150000
125000
100000
75000
50000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year


Cow and bull supply, western Canada (1980-2005)
Actual
Predicted
No. of heads
250000
225000
200000
175000
150000
125000
100000
75000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

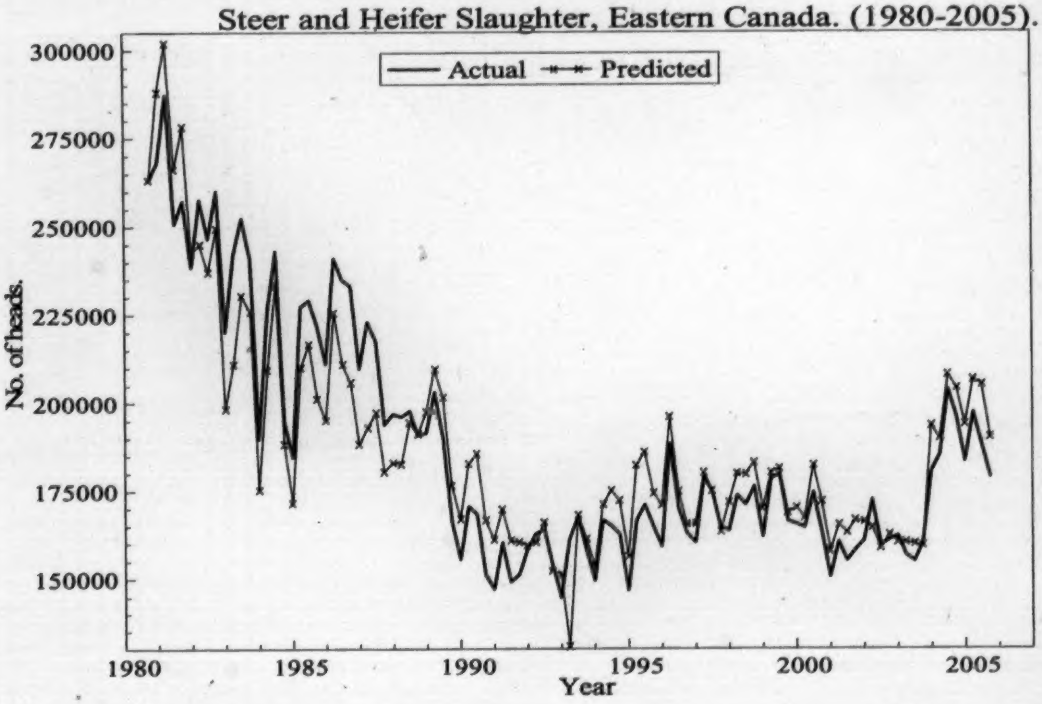

Steer and heifer supply, U.S. (1980-2005)
Actual
Predicted
million heads
15.85
15.80
15.75
15.70
15.65
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year


Steer and heifer supply, western Canada (1980-2005)
Actual
Predicted
Million heads
13.6
13.5
13.4
13.3
13.2
13.1
13.0
12.9
12.8
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

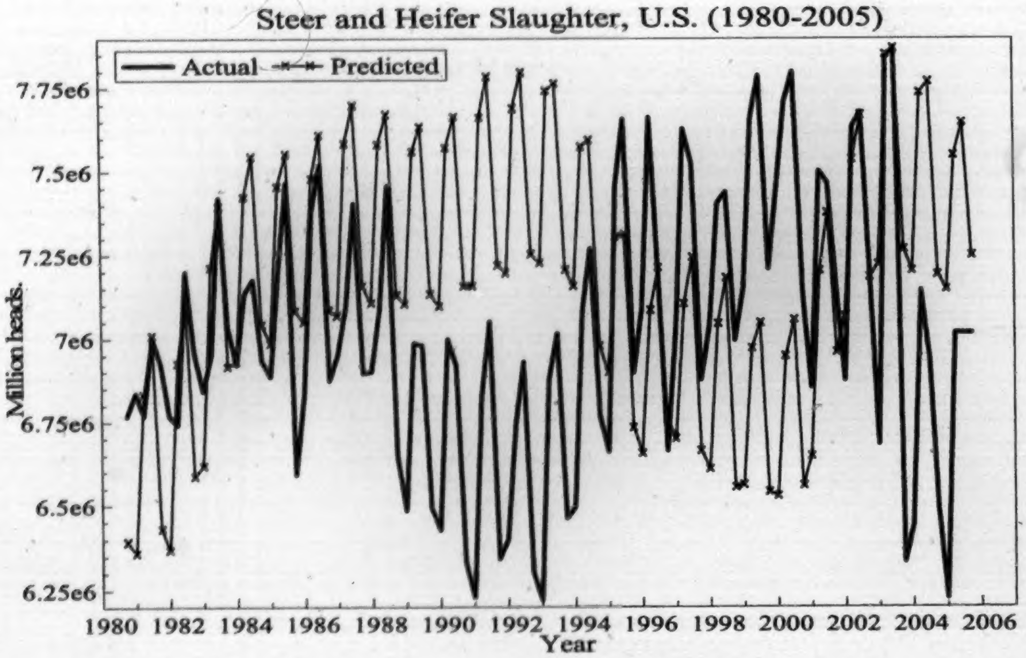

Steer and heifer supply, eastern Canada (1980-2005)
Actual
Predicted
Million heads
12.5
12.4
12.3
12.2
12.1
12.0
11.9
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year



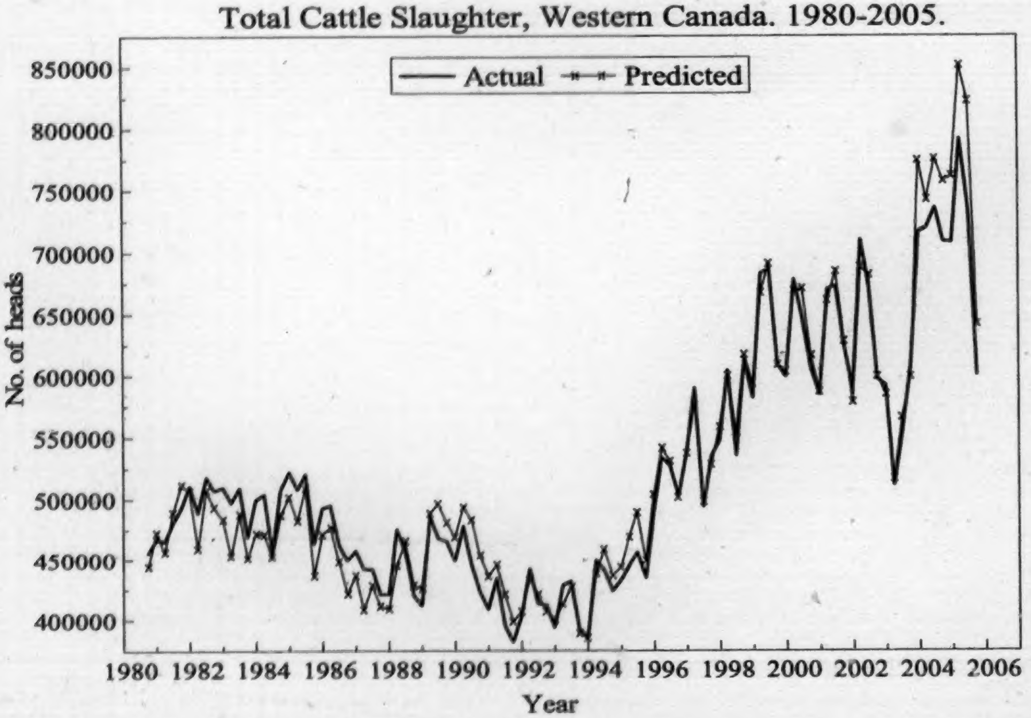
Steer and Heifer Slaughter, Western Canada. (1980-2005)



Steer and Heifer Slaughter, Eastern Canada. (1980-2005).

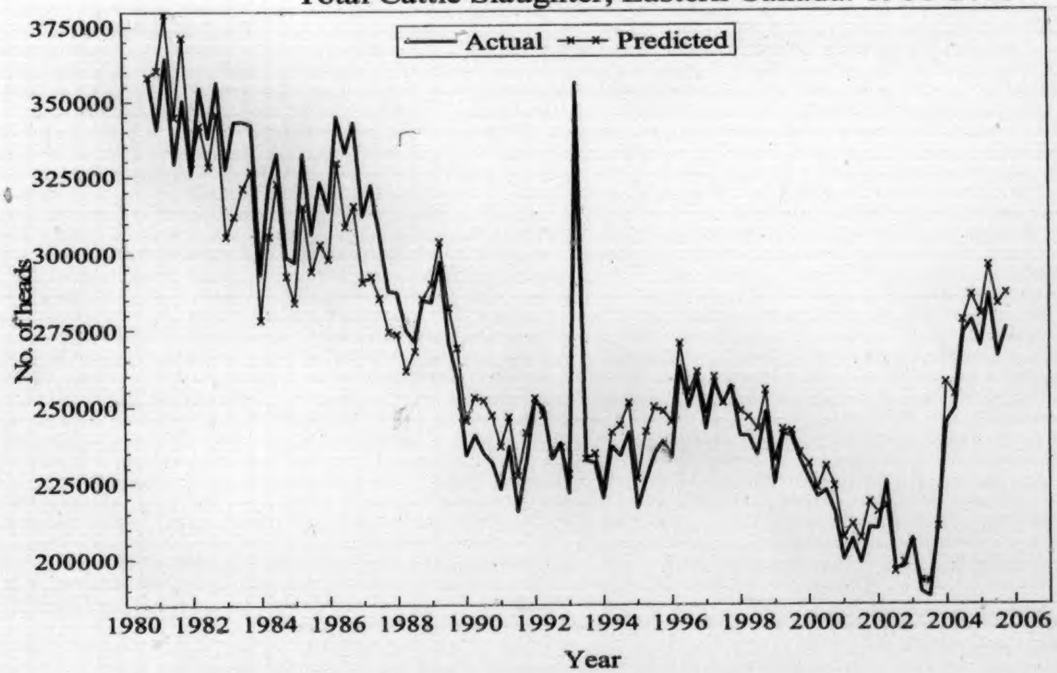


Steer and Heifer Slaughter, U.S. (1980-2005)

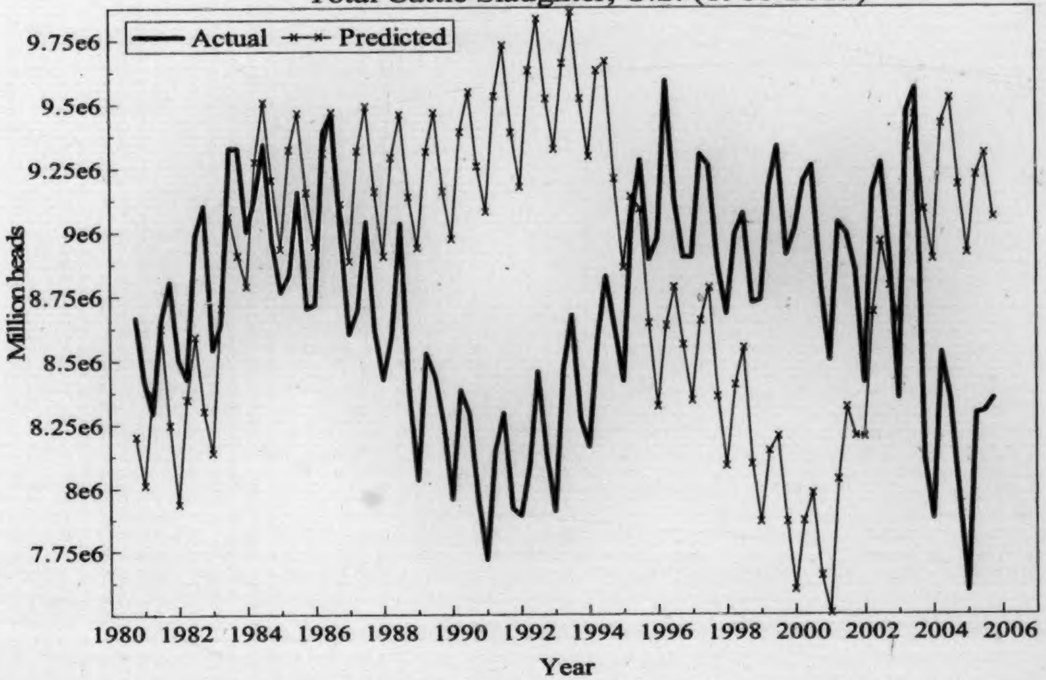


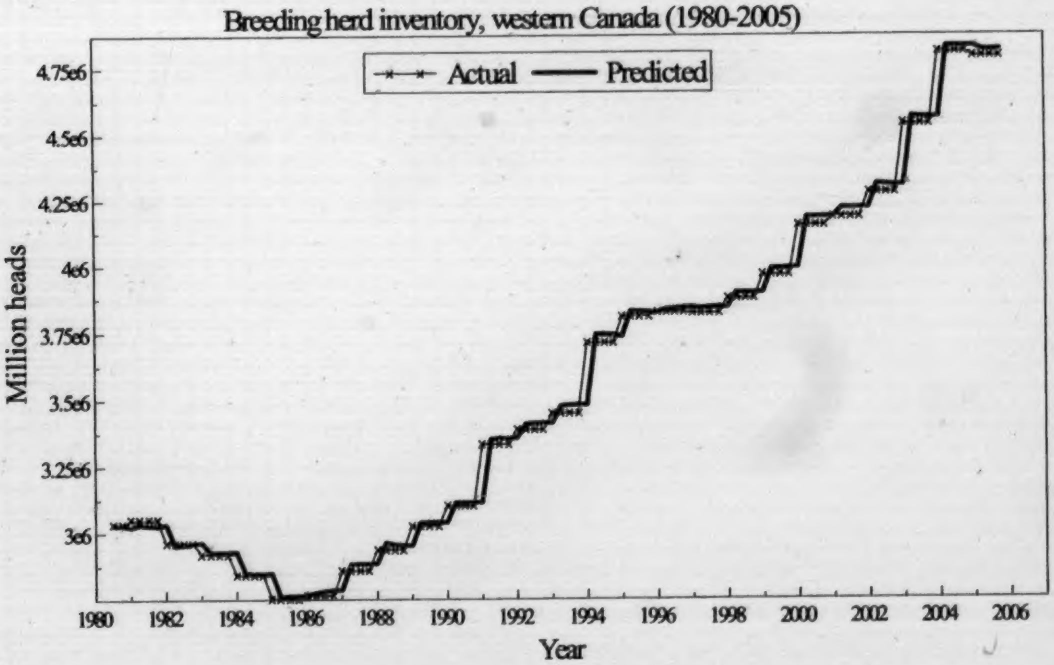
Total Cattle Slaughter, Western Canada. 1980-2005.

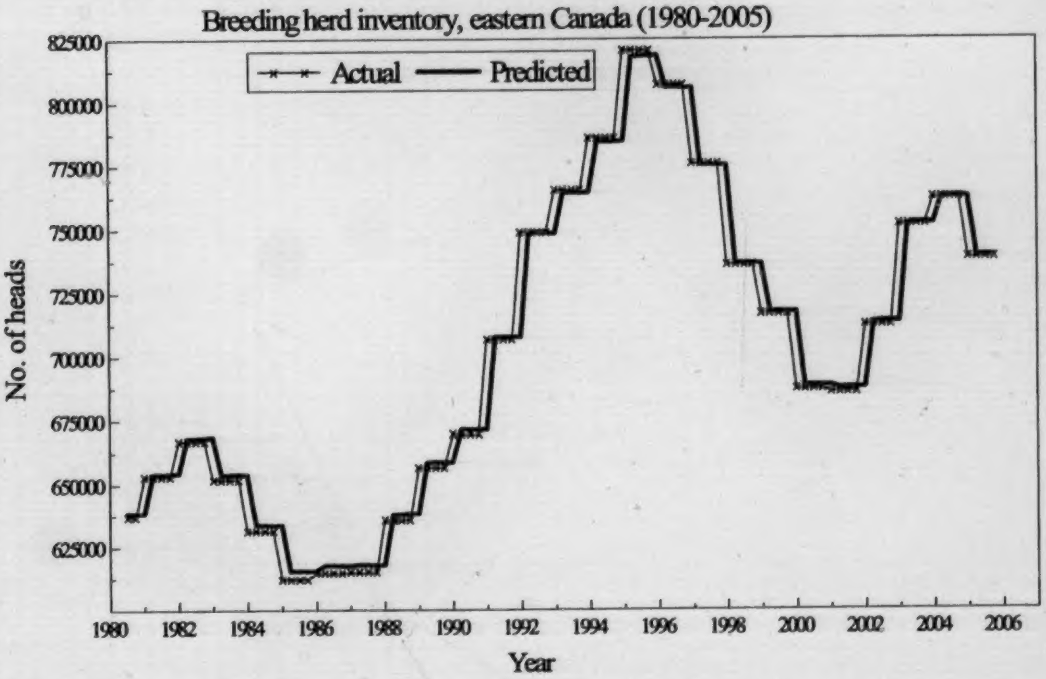
Total Cattle Slaughter, Eastern Canada. 1980-2005.

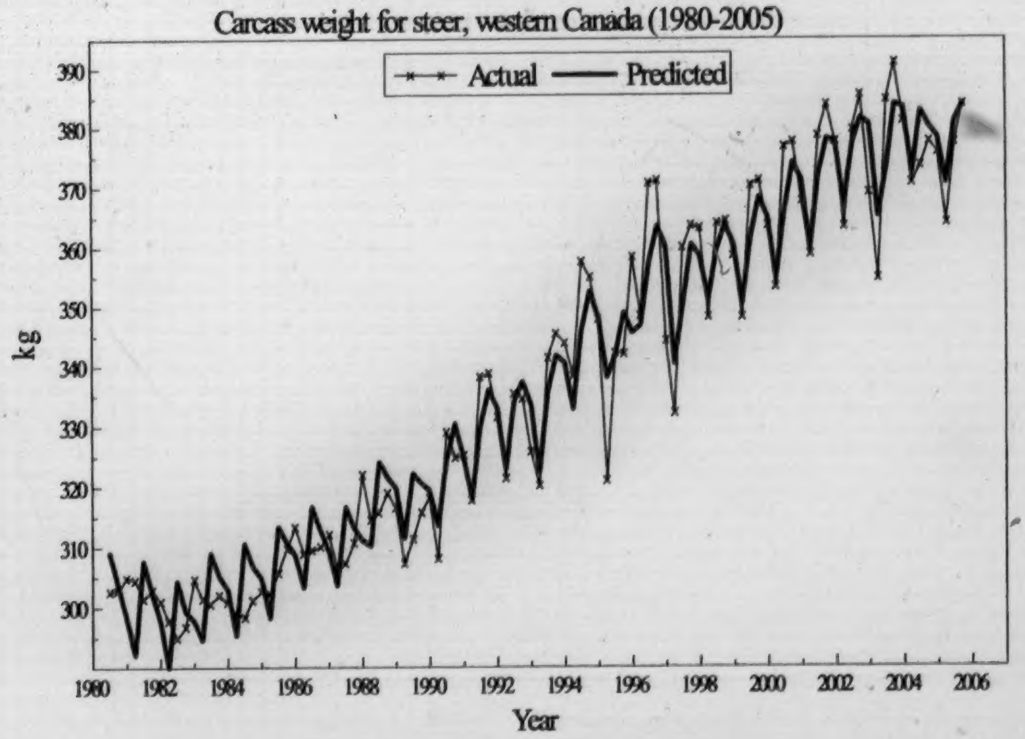


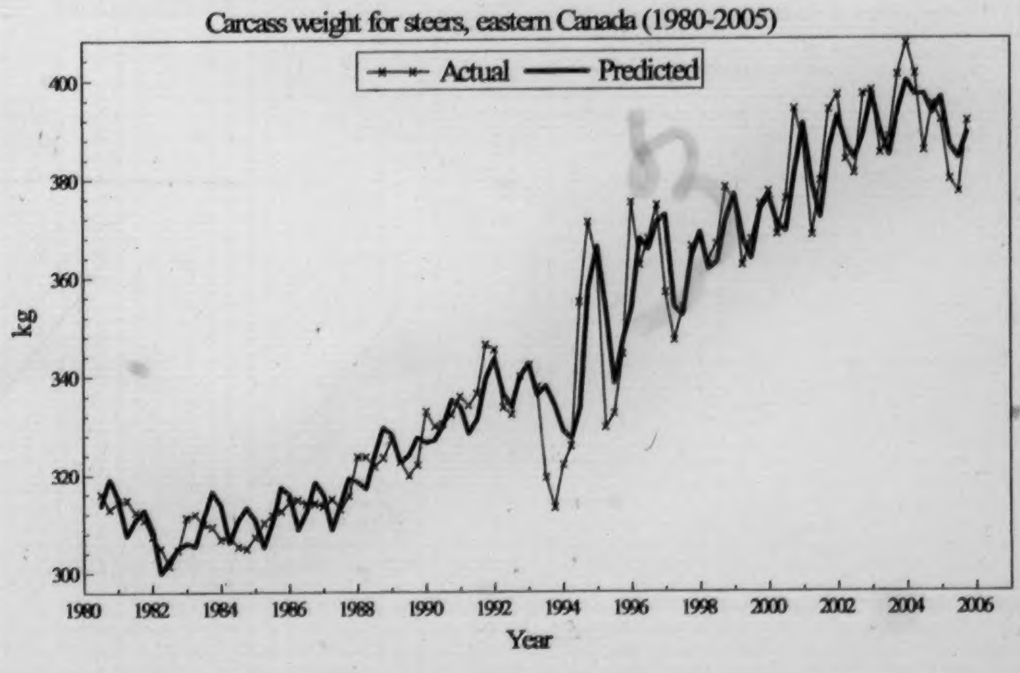
Total Cattle Slaughter, U.S. (1980-2005)

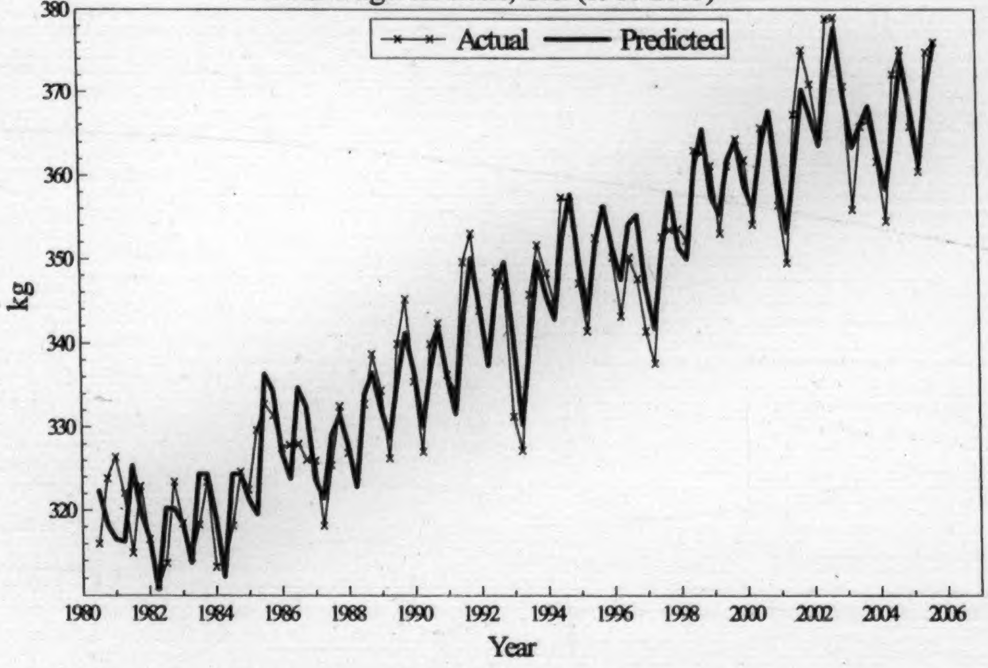



Breeding herd inventory, western Canada (1980-2005)

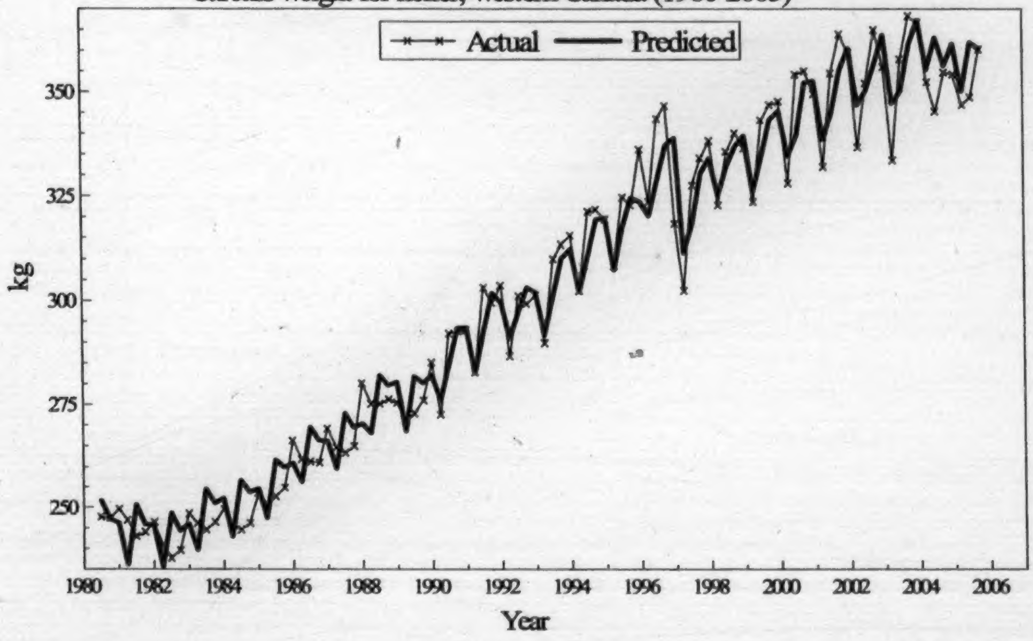

Breeding herd inventory, eastern Canada (1980-2005)


Carcass weight for steer, western Canada (1980-2005)
Actual
Predicted
kg
390
380
370
360
350
340
330
320
310
300
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

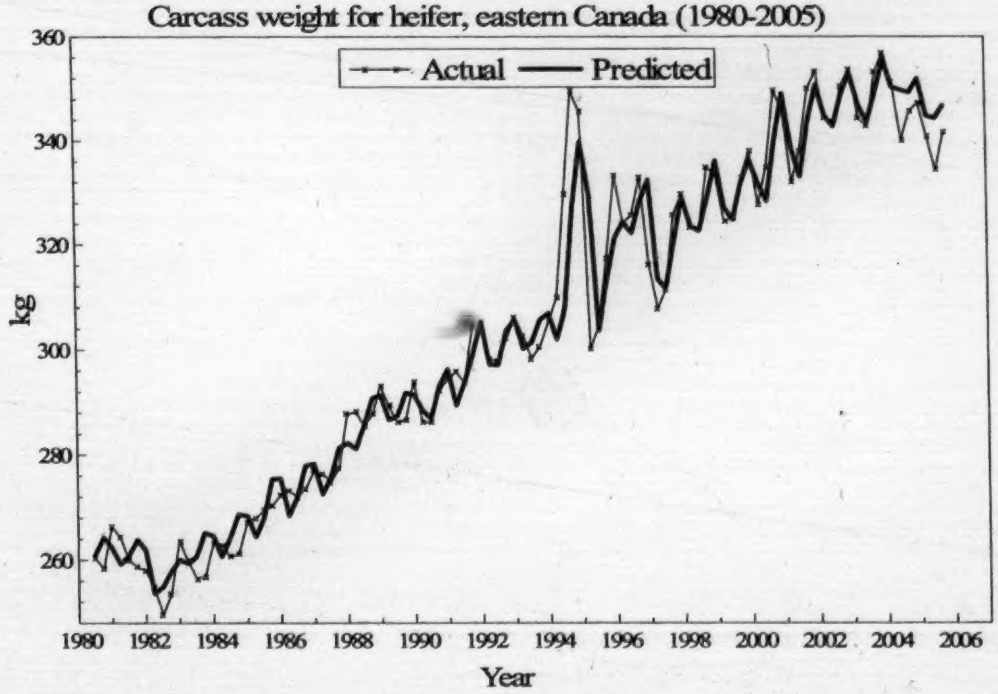

Carcass weight for steers, eastern Canada (1980-2005)
Actual
Predicted
kg
400
380
360
340
320
300
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

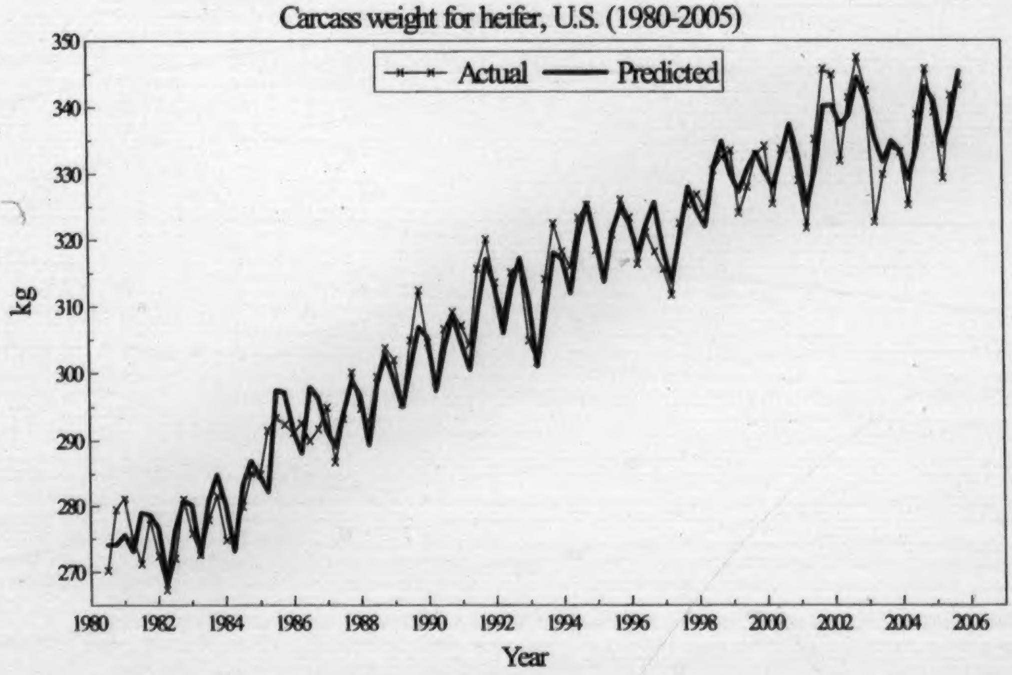


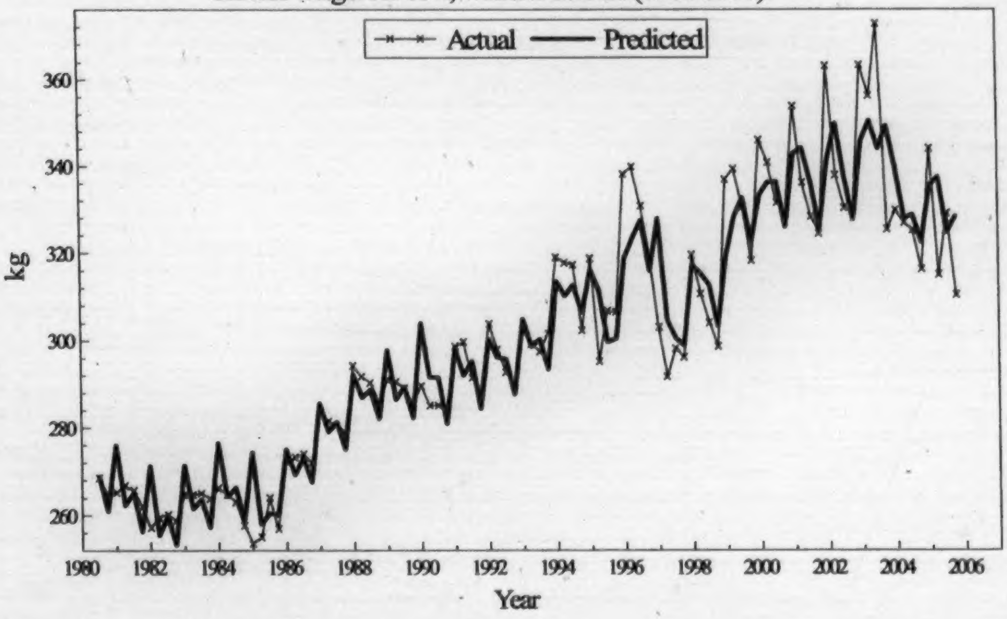
Carcass weight for steers, U.S. (1980-2005)



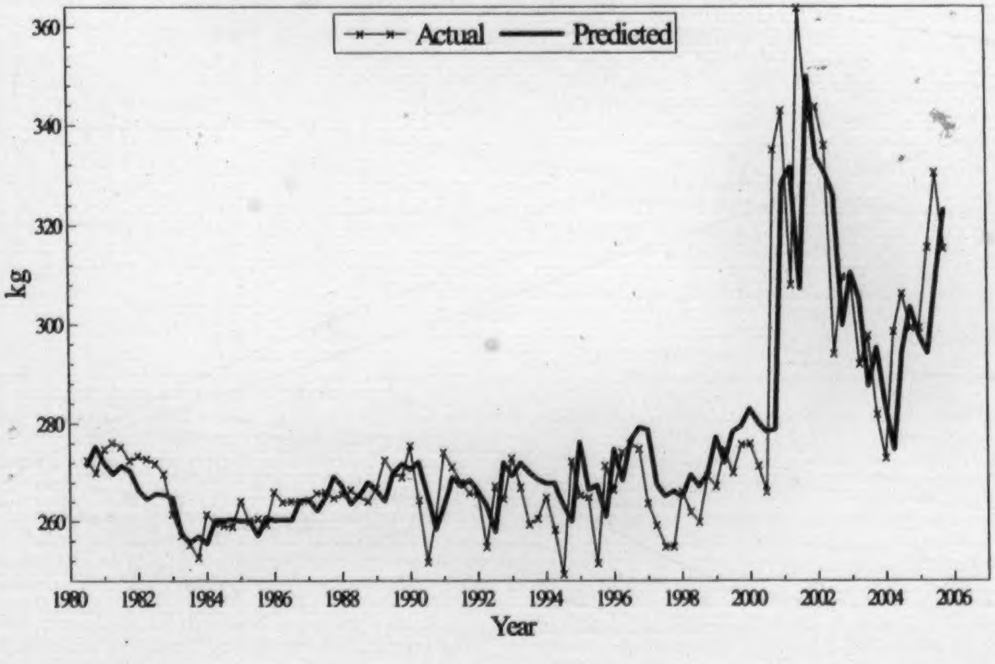
Carcass weight for heifer, western Canada (1980-2005)


Carcass weight for heifer, eastern Canada (1980-2005)
Actual
Predicted
kg
360
340
320
300
280
260
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

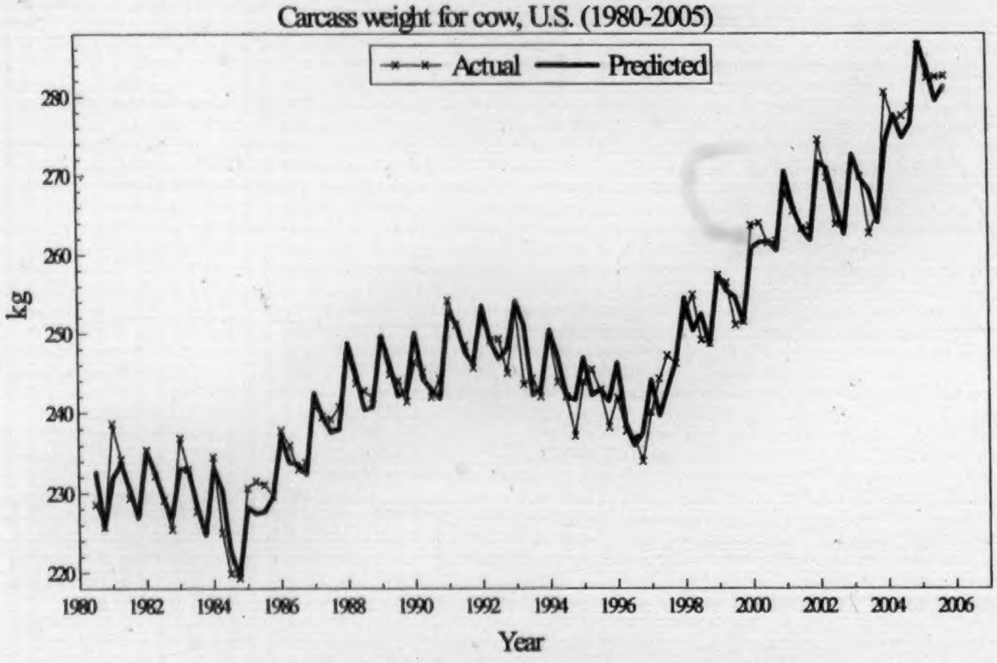

Carcass weight for heifer, U.S. (1980-2005)
Actual
Predicted
kg
350
340
330
320
310
300
290
280
270
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

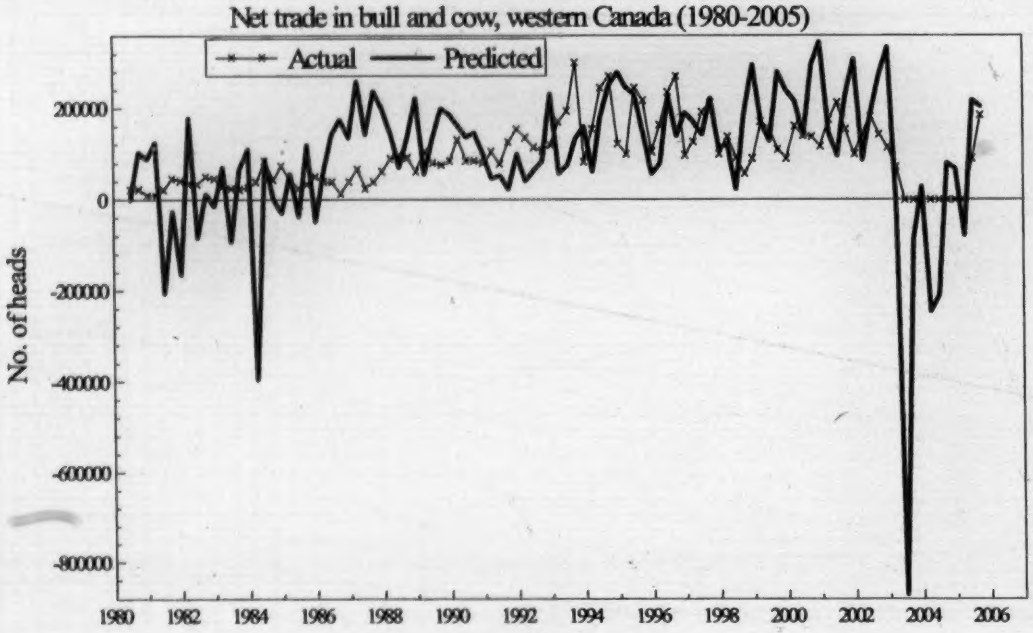


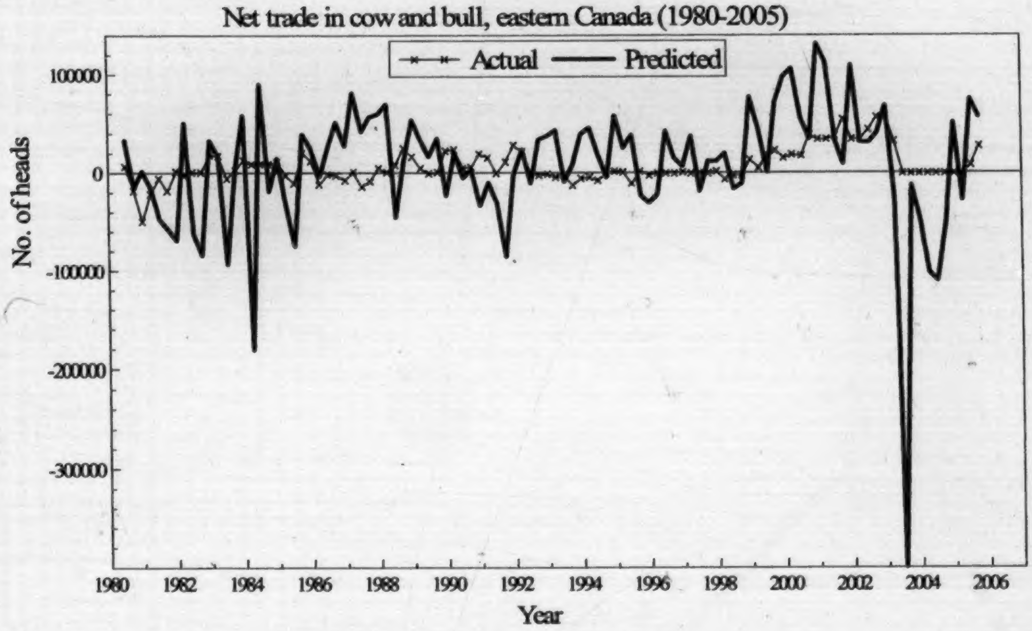
Carcass weight for cow, western Canada (1980-2005)



Carcass weight for cow, eastern Canada (1980-2005)


Carcass weight for cow, U.S. (1980-2005)


Net trade in bull and cow, western Canada (1980-2005)


Net trade in cow and bull, eastern Canada (1980-2005)
Actual
Predicted
No. of heads
100000
0
-100000
-200000
-300000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Year

APPENDIX VIIIA: RETAIL PRICES OF STEER, HEIFER AND COWS AND WHOLESALE PRICE OF STEER.

DOLLAR/CWT ($/CWT) (1980:1 2005:4)

PERIOD	RPS1	RPS2	RPS3	RPH1	RPH2	RPH3	RPC1	RPC2	RPC3	WPS1	WPS2	WPS3
1980Q1	201.65	201.65	175.03	201.65	201.65	148.66	190.67	190.67	130.67	148.66	148.66	127.97
1980Q2	208.80	208.80	174.00	208.80	208.80	147.72	193.83	193.83	127.97	145.93	145.93	128.20
1980Q3	208.80	208.80	180.70	208.80	208.80	154.53	193.83	193.83	130.70	153.31	153.31	136.43
1980Q4	223.72	223.72	186.43	223.72	223.72	160.84	210.48	210.48	129.93	156.01	156.01	131.67
1981Q1	223.72	223.72	181.90	223.72	223.72	156.71	210.48	210.48	132.93	149.97	149.97	124.77
1981Q2	219.80	219.80	180.60	219.80	219.80	154.15	203.90	203.90	131.47	156.09	156.09	132.27
1981Q3	219.80	219.80	189.67	219.80	219.80	163.34	203.90	203.90	138.13	151.12	151.12	136.23
1981Q4	211.70	211.70	184.63	211.70	211.70	158.98	195.63	195.63	130.23	143.65	143.65	123.00
1982Q1	211.70	211.70	181.93	211.70	211.70	156.57	195.63	195.63	135.30	143.27	143.27	128.73
1982Q2	211.73	211.73	194.83	211.73	211.73	167.39	196.97	196.97	145.43	169.98	169.98	146.07
1982Q3	240.96	240.96	199.20	240.96	240.96	172.79	220.59	220.59	145.50	152.15	152.15	133.53
1982Q4	215.36	215.36	189.53	215.36	215.36	164.81	199.73	199.73	132.10	142.50	142.50	124.23
1983Q1	206.58	206.58	185.33	206.58	206.58	160.58	193.37	193.37	137.90	144.26	144.26	126.43
1983Q2	216.61	216.61	191.97	216.61	216.61	166.49	200.14	200.14	142.30	162.20	162.20	136.90
1983Q3	228.45	228.45	189.23	228.45	228.45	165.22	208.89	208.89	135.40	145.28	145.28	125.03
1983Q4	226.35	226.35	185.73	226.35	226.35	161.77	207.96	207.96	129.47	147.20	147.20	126.00
1984Q1	230.80	230.80	192.00	230.80	230.80	168.48	207.20	207.20	143.77	161.16	161.16	136.83
1984Q2	239.39	239.39	199.27	239.39	239.39	174.77	220.03	220.03	142.93	164.76	164.76	136.43
1984Q3	245.49	245.49	200.83	245.49	245.49	176.78	222.82	222.82	138.80	160.82	160.82	137.07
1984Q4	247.94	247.94	203.80	247.94	247.94	178.94	227.77	227.77	137.77	155.29	155.29	138.77
1985Q1	250.20	250.20	207.03	250.20	250.20	182.89	224.03	224.03	148.10	165.55	165.55	138.47
1985Q2	256.16	256.16	207.20	256.16	256.16	183.33	234.44	234.44	145.50	165.68	165.68	131.03
1985Q3	256.35	256.35	200.50	256.35	256.35	176.81	233.33	233.33	139.20	149.98	149.98	120.20
1985Q4	241.28	241.28	206.27	241.28	241.28	181.97	221.41	221.41	143.00	164.60	164.60	144.57
1986Q1	254.28	254.28	209.07	254.28	254.28	185.90	231.37	231.37	151.83	154.96	154.96	132.77
1986Q2	235.56	235.56	201.57	235.56	235.56	179.82	212.72	212.72	145.10	155.93	155.93	126.27
1986Q3	254.01	254.01	205.73	254.01	254.01	181.84	228.26	228.26	146.10	162.08	162.08	135.47
1986Q4	251.32	251.32	206.47	251.32	251.32	184.74	229.15	229.15	148.10	167.68	167.68	137.13
1987Q1	269.28	269.28	199.27	269.28	269.28	180.33	244.96	244.96	147.23	162.15	162.15	130.30
1987Q2	266.17	266.17	204.63	266.17	266.17	184.50	243.27	243.27	154.07	180.62	180.62	147.10

APPENDIX VIIIA CONT'D

1987Q3	281.46	281.46	207.80	281.46	281.46	187.26	254.19	254.19	152.73	175.46	175.46	137.40
1987Q4	274.78	274.78	206.30	274.78	274.78	186.24	251.89	251.89	149.37	168.46	168.46	134.13
1988Q1	273.12	273.12	196.83	273.12	273.12	177.52	253.67	253.67	148.93	170.64	170.64	133.57
1988Q2	278.02	278.02	198.50	278.02	278.02	179.22	254.13	254.13	149.23	175.54	175.54	140.13
1988Q3	278.51	278.51	202.37	278.51	278.51	182.13	254.38	254.38	147.53	163.57	163.57	130.93
1988Q4	281.65	281.65	201.20	281.65	281.65	180.42	256.47	256.47	143.70	165.00	165.00	135.93
1989Q1	270.68	270.68	201.20	270.68	270.68	181.74	245.74	245.74	149.93	176.11	176.11	136.87
1989Q2	282.83	282.83	205.70	282.83	282.83	186.25	259.17	259.17	154.33	174.37	174.37	139.00
1989Q3	286.90	286.90	208.03	286.90	286.90	186.67	261.86	261.86	149.40	168.75	168.75	133.90
1989Q4	287.03	287.03	205.13	287.03	287.03	185.74	262.86	262.86	143.47	171.61	171.61	135.87
1990Q1	281.66	281.66	208.50	281.66	281.66	189.33	258.37	258.37	153.10	176.06	176.06	142.97
1990Q2	284.66	284.66	211.20	284.66	284.66	192.93	263.31	263.31	158.27	179.00	179.00	142.33
1990Q3	294.40	294.40	212.20	294.40	294.40	191.43	269.70	269.70	151.13	175.51	175.51	140.30
1990Q4	296.89	296.89	220.70	296.89	296.89	199.36	274.35	274.35	157.43	181.35	181.35	149.53
1991Q1	292.41	292.41	217.80	292.41	292.41	198.90	269.06	269.06	164.63	182.77	182.77	142.00
1991Q2	298.34	298.34	217.73	298.34	298.34	198.14	271.95	271.95	163.57	186.95	186.95	140.37
1991Q3	299.05	299.05	213.33	299.05	299.05	192.56	272.23	272.23	151.57	175.54	175.54	130.37
1991Q4	287.43	287.43	207.77	287.43	287.43	188.37	263.66	263.66	144.60	168.52	168.52	129.33
1992Q1	287.08	287.08	214.73	287.08	287.08	195.87	261.03	261.03	157.27	170.51	170.51	138.10
1992Q2	293.88	293.88	221.37	293.88	293.88	201.45	270.24	270.24	162.60	180.30	180.30	140.67
1992Q3	288.71	288.71	221.37	288.71	288.71	200.23	263.41	263.41	158.37	180.10	180.10	137.13
1992Q4	290.17	290.17	234.20	290.17	290.17	213.18	266.16	266.16	165.40	180.93	180.93	146.70
1993Q1	297.24	297.24	232.70	297.24	297.24	214.23	273.17	273.17	177.83	195.52	195.52	150.80
1993Q2	303.19	303.19	242.93	303.19	303.19	223.97	275.74	275.74	180.90	203.47	203.47	154.70
1993Q3	319.94	319.94	246.90	319.94	319.94	224.34	289.65	289.65	174.37	198.82	198.82	149.87
1993Q4	307.87	307.87	249.43	307.87	307.87	228.75	280.70	280.70	171.70	194.46	194.46	148.43
1994Q1	303.85	303.85	248.07	303.85	303.85	226.65	273.67	273.67	177.83	197.93	197.93	150.60
1994Q2	310.39	310.39	255.20	310.39	310.39	233.95	279.19	279.19	180.57	209.79	209.79	149.50
1994Q3	309.69	309.69	250.90	309.69	309.69	227.01	277.44	277.44	169.93	198.92	198.92	146.33
1994Q4	310.91	310.91	250.80	310.91	310.91	228.59	279.79	279.79	166.77	195.06	195.06	145.93
1995Q1	300.71	300.71	257.63	300.71	300.71	236.33	271.31	271.31	181.00	206.15	206.15	153.63
1995Q2	299.77	299.77	248.53	299.77	299.77	229.17	269.70	269.70	178.63	198.87	198.87	141.83

APPENDIX VIIIA CONT'D

1995Q3	281.46	281.46	207.80	281.46	281.46	187.26	254.19	254.19	152.73	175.46	175.46	137.40
1995Q4	274.78	274.78	206.30	274.78	274.78	186.24	251.89	251.89	149.37	168.46	168.46	134.13
1996Q1	273.12	273.12	196.83	273.12	273.12	177.52	253.67	253.67	148.93	170.64	170.64	133.57
1996Q2	278.02	278.02	198.50	278.02	278.02	179.22	254.13	254.13	149.23	175.54	175.54	140.13
1996Q3	278.51	278.51	202.37	278.51	278.51	182.13	254.38	254.38	147.53	163.57	163.57	130.93
1996Q4	281.65	281.65	201.20	281.65	281.65	180.42	256.47	256.47	143.70	165.00	165.00	135.93
1997Q1	270.68	270.68	201.20	270.68	270.68	181.74	245.74	245.74	149.93	176.11	176.11	136.87
1997Q2	282.83	282.83	205.70	282.83	282.83	186.25	259.17	259.17	154.33	174.37	174.37	139.00
1997Q3	286.90	286.90	208.03	286.90	286.90	186.67	261.86	261.86	149.40	168.75	168.75	133.90
1997Q4	287.03	287.03	205.13	287.03	287.03	185.74	262.86	262.86	143.47	171.61	171.61	135.87
1998Q1	281.66	281.66	208.50	281.66	281.66	189.33	258.37	258.37	153.10	176.06	176.06	142.97
1998Q2	284.66	284.66	211.20	284.66	284.66	192.93	263.31	263.31	158.27	179.00	179.00	142.33
1998Q3	294.40	294.40	212.20	294.40	294.40	191.43	269.70	269.70	151.13	175.51	175.51	140.30
1998Q4	296.89	296.89	220.70	296.89	296.89	199.36	274.35	274.35	157.43	181.35	181.35	149.53
1999Q1	292.41	292.41	217.80	292.41	292.41	198.90	269.06	269.06	164.63	182.77	182.77	142.00
1999Q2	298.34	298.34	217.73	298.34	298.34	198.14	271.95	271.95	163.57	186.95	186.95	140.37
1999Q3	299.05	299.05	213.33	299.05	299.05	192.56	272.23	272.23	151.57	175.54	175.54	130.37
1999Q4	287.43	287.43	207.77	287.43	287.43	188.37	263.66	263.66	144.60	168.52	168.52	129.33
2000Q1	287.08	287.08	214.73	287.08	287.08	195.87	261.03	261.03	157.27	170.51	170.51	138.10
2000Q2	293.88	293.88	221.37	293.88	293.88	201.45	270.24	270.24	162.60	180.30	180.30	140.67
2000Q3	288.71	288.71	221.37	288.71	288.71	200.23	263.41	263.41	158.37	180.10	180.10	137.13
2000Q4	290.17	290.17	234.20	290.17	290.17	213.18	266.16	266.16	165.40	180.93	180.93	146.70
2001Q1	297.24	297.24	232.70	297.24	297.24	214.23	273.17	273.17	177.83	195.52	195.52	150.80
2001Q2	303.19	303.19	242.93	303.19	303.19	223.97	275.74	275.74	180.90	203.47	203.47	154.70
2001Q3	319.94	319.94	246.90	319.94	319.94	224.34	289.65	289.65	174.37	198.82	198.82	149.87
2001Q4	307.87	307.87	249.43	307.87	307.87	228.75	280.70	280.70	171.70	194.46	194.46	148.43
2002Q1	303.85	303.85	248.07	303.85	303.85	226.65	273.67	273.67	177.83	197.93	197.93	150.60
2002Q2	310.39	310.39	255.20	310.39	310.39	233.95	279.19	279.19	180.57	209.79	209.79	149.50
2002Q3	309.69	309.69	250.90	309.69	309.69	227.01	277.44	277.44	169.93	198.92	198.92	146.33
2002Q4	310.91	310.91	250.80	310.91	310.91	228.59	279.79	279.79	166.77	195.06	195.06	145.93
2003Q1	300.71	300.71	257.63	300.71	300.71	236.33	271.31	271.31	181.00	206.15	206.15	153.63
2003Q2	299.77	299.77	248.53	299.77	299.77	229.17	269.70	269.70	178.63	198.87	198.87	141.83

APPENDIX VIIIA CONT'D

2003Q3	357.58	357.58	335.33	357.58	357.58	302.46	323.86	323.86	240.93	239.32	239.32	200.23
2003Q4	370.28	370.28	356.87	370.28	370.28	325.36	337.16	337.16	258.40	256.61	256.61	218.90
2004Q1	372.66	372.66	339.10	372.66	372.66	312.47	339.90	339.90	263.10	253.74	253.74	178.43
2004Q2	392.29	392.29	359.33	392.29	392.29	329.59	356.46	356.46	280.70	263.35	263.35	209.10
2004Q3	406.86	406.86	352.63	406.86	406.86	321.24	370.77	370.77	263.13	267.22	267.22	181.77
2004Q4	391.03	391.03	321.90	391.03	391.03	296.71	357.12	357.12	239.10	264.90	264.90	170.53
2005Q1	395.66	395.66	326.70	395.66	395.66	303.07	360.51	360.51	256.00	259.92	259.92	180.73
2005Q2	399.23	399.23	339.93	399.23	399.23	310.72	363.54	363.54	266.27	271.53	271.53	188.37
2005Q3	391.45	391.45	311.60	391.45	391.45	284.17	356.25	356.25	234.80	260.54	260.54	163.80
2005Q4	387.12	387.12	308.37	387.12	387.12	281.55	354.21	354.21	231.73	254.11	254.11	178.63

R = Retail. W = Wholesale. F = Farm. See Appendix I for definition of data.

APPENDIX VIIIB: FARM PRICES OF STEERS, HEIFERS, COWS AND FEEDER CATTLE.

DOLLAR/CWT ($/CWT) (1980:1 2005:4)

PERIOD	PS1	PS2	PS3	PH1	PH2	PH3	PC1	PC2	PC3	PFC1	PFC2	PFC3
1980Q1	87.18	92.21	121.43	87.51	93.84	103.17	69.17	71.19	90.67	99.45	93.60	87.20
1980Q2	81.86	86.85	119.70	83.30	88.93	101.63	63.98	65.13	88.03	82.87	81.13	74.85
1980Q3	87.06	93.90	130.13	87.59	93.73	111.29	66.64	67.11	94.17	82.87	86.05	77.12
1980Q4	90.58	94.55	124.83	87.75	91.89	107.72	61.55	65.18	87.03	88.69	83.96	76.91
1981Q1	86.33	91.36	116.97	86.45	92.35	100.77	64.43	65.86	85.43	82.92	80.93	72.78
1981Q2	89.55	92.36	125.93	89.82	93.54	107.47	68.26	65.01	91.63	81.27	83.65	68.61
1981Q3	85.13	92.46	127.60	83.74	92.54	109.87	66.61	66.30	92.90	76.67	77.37	64.79
1981Q4	80.33	87.61	114.80	81.59	88.14	98.85	55.57	58.17	81.00	70.65	73.86	64.64
1982Q1	78.47	86.64	119.73	78.48	86.38	103.05	57.74	59.75	89.07	69.32	73.07	63.84
1982Q2	94.22	99.88	137.23	92.09	96.46	117.90	65.51	64.67	102.43	78.61	81.72	68.15
1982Q3	86.94	94.13	126.13	87.87	93.88	109.41	66.24	66.43	92.13	80.91	80.36	67.18
1982Q4	80.16	85.67	116.03	86.40	89.23	100.90	58.49	56.82	80.87	77.19	81.01	64.43
1983Q1	80.53	88.77	118.77	83.05	94.34	102.92	61.49	61.22	88.40	81.27	87.26	71.09
1983Q2	88.59	95.49	129.73	87.91	97.05	112.53	66.63	66.55	96.20	84.64	88.84	70.74
1983Q3	80.88	87.76	118.67	82.80	89.57	103.64	63.33	64.08	84.97	82.92	79.33	63.93
1983Q4	84.02	89.85	120.53	84.19	92.48	104.96	56.30	58.25	84.07	83.39	83.99	65.70
1984Q1	91.12	98.28	132.47	91.58	101.06	116.25	64.54	65.60	99.20	86.34	85.99	69.02
1984Q2	92.76	101.04	133.77	68.86	76.24	117.33	68.60	70.93	95.93	84.17	87.19	66.93
1984Q3	89.58	100.45	134.20	90.81	101.45	118.13	67.35	71.00	92.77	82.34	87.30	65.39
1984Q4	91.75	99.52	135.40	91.19	100.43	118.85	61.58	63.29	91.53	84.35	87.17	67.71
1985Q1	90.68	100.14	133.13	90.00	102.65	117.57	64.92	67.31	95.27	83.60	86.90	72.63
1985Q2	89.84	95.57	126.03	88.67	97.94	111.52	68.55	67.65	88.53	87.02	92.36	70.81
1985Q3	80.13	86.21	114.20	81.78	89.78	100.71	63.91	64.47	79.27	81.13	84.81	65.23
1985Q4	91.88	96.52	137.27	92.34	99.95	121.11	61.45	62.51	95.17	84.09	88.21	66.24
1986Q1	87.25	97.89	126.43	86.68	100.76	112.41	69.21	67.16	91.80	87.50	87.83	66.96
1986Q2	85.33	93.56	119.07	84.67	97.45	106.24	67.40	66.17	85.70	89.66	92.47	63.84
1986Q3	90.24	97.45	130.30	92.20	100.63	115.14	69.75	69.12	92.50	97.08	95.39	67.38
1986Q4	95.05	100.71	132.23	95.85	105.88	118.33	65.80	67.76	94.83	100.45	100.23	67.11
1987Q1	94.09	100.67	127.73	94.07	104.25	115.61	74.51	74.27	94.43	108.76	104.96	73.22
1987Q2	103.85	109.69	143.67	104.49	112.10	129.52	79.52	79.75	108.13	114.41	110.27	78.93

APPENDIX VIIIB CONT'D

1987Q3	100.19	107.98	135.47	101.03	111.21	122.05	81.72	80.91	99.57	118.67	111.38	85.69
1987Q4	100.13	107.34	133.97	102.68	111.36	120.94	77.38	79.15	96.97	120.65	115.00	85.02
1988Q1	100.47	107.89	135.10	101.37	111.69	121.85	81.25	81.44	102.20	122.76	114.20	91.10
1988Q2	100.73	111.02	139.90	101.74	113.93	126.33	80.40	79.49	105.20	110.04	116.97	91.14
1988Q3	93.24	100.19	130.27	96.21	103.88	117.24	77.73	73.32	94.97	106.10	96.18	88.84
1988Q4	94.94	100.47	135.20	97.59	104.28	121.26	71.76	68.50	96.57	106.02	99.08	92.23
1989Q1	100.83	105.44	138.60	101.75	109.02	125.21	75.67	72.22	103.30	103.27	97.83	94.87
1989Q2	96.53	106.72	138.30	99.01	110.03	125.21	77.14	73.05	103.77	103.86	95.75	92.53
1989Q3	94.87	103.91	132.93	97.90	107.38	119.26	80.00	74.99	95.47	102.13	94.84	91.61
1989Q4	99.45	105.46	138.33	101.01	108.79	125.27	73.69	73.92	96.83	104.48	98.70	83.52
1990Q1	103.13	106.41	144.90	105.43	104.61	131.61	104.91	78.22	106.43	101.37	93.28	94.13
1990Q2	101.83	107.97	141.17	104.61	105.96	128.96	104.09	80.95	105.80	105.29	99.18	100.32
1990Q3	99.17	106.07	139.73	102.74	103.68	126.09	102.22	79.96	99.53	106.05	93.32	100.04
1990Q4	102.42	108.90	147.23	105.07	105.03	132.99	73.73	73.06	105.03	103.89	102.21	90.76
1991Q1	100.94	105.93	142.20	102.50	102.95	129.84	75.65	73.82	107.47	109.72	98.72	97.31
1991Q2	94.97	104.00	138.03	97.53	101.39	125.61	74.74	75.90	103.73	117.74	109.23	107.35
1991Q3	85.53	95.91	124.40	90.92	95.19	112.33	73.11	71.75	88.43	111.29	96.40	99.85
1991Q4	82.06	87.34	125.20	86.61	86.72	113.50	65.89	64.75	87.17	103.99	100.47	84.14
1992Q1	89.88	95.70	138.20	93.29	93.38	126.03	66.84	68.32	101.20	101.20	95.58	93.90
1992Q2	91.65	101.94	140.70	94.12	99.96	128.06	71.80	71.48	103.33	106.28	96.95	93.85
1992Q3	91.45	101.43	138.97	94.80	98.90	125.72	70.61	74.91	99.43	106.69	87.70	94.86
1992Q4	96.61	108.36	148.73	99.76	104.96	135.38	69.38	76.33	105.07	110.70	116.22	90.97
1993Q1	107.33	113.15	154.60	109.49	111.24	142.33	76.63	80.73	118.13	115.76	114.63	99.51
1993Q2	104.06	116.47	155.33	107.14	113.99	143.19	80.19	83.39	115.67	125.03	118.48	104.17
1993Q3	100.77	110.93	149.90	103.98	108.85	136.22	83.72	86.84	105.87	137.51	126.64	100.08
1993Q4	101.88	109.33	147.63	103.35	107.43	135.38	77.80	81.53	101.60	133.26	124.69	94.83
1994Q1	103.87	112.01	152.47	106.32	109.95	139.31	75.86	77.01	109.27	131.13	121.54	98.96
1994Q2	99.28	112.65	148.17	101.68	110.30	135.85	78.88	79.67	104.87	139.00	125.37	94.16
1994Q3	98.09	108.05	142.33	103.26	106.93	128.79	79.37	76.69	96.40	134.01	122.53	86.42
1994Q4	102.33	105.64	146.43	107.86	103.53	133.46	70.63	71.06	97.37	117.96	104.91	84.58
1995Q1	110.38	112.91	156.63	114.71	111.81	143.69	76.45	74.27	110.07	118.06	108.31	86.64
1995Q2	99.58	105.25	137.67	111.86	109.47	126.96	73.49	70.97	98.97	108.95	104.14	78.62

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1995Q3	95.40	102.74	132.97	104.26	105.15	121.04	67.88	66.10	91.63	97.18	93.56	69.30
1995Q4	96.44	100.27	141.00	99.53	97.44	129.19	57.61	58.08	94.37	85.42	87.83	64.45
1996Q1	91.69	94.85	135.07	91.09	93.09	124.70	60.41	58.38	93.30	67.18	71.26	62.12
1996Q2	87.63	91.85	128.70	86.60	89.26	118.65	60.92	57.63	89.20	67.94	71.29	59.86
1996Q3	97.97	101.76	144.87	97.77	96.70	132.85	62.42	59.85	98.00	75.12	73.72	64.08
1996Q4	100.13	105.05	149.00	99.86	99.29	136.42	57.17	56.04	100.30	74.23	74.96	67.49
1997Q1	99.45	101.38	140.10	98.60	98.68	129.55	64.33	65.42	98.57	85.76	79.93	81.28
1997Q2	99.41	104.20	142.87	98.35	100.90	131.93	69.93	70.57	103.33	100.84	93.39	90.28
1997Q3	96.92	96.59	142.60	97.17	99.01	130.43	67.18	67.48	99.97	111.57	100.50	92.65
1997Q4	100.81	100.48	146.67	101.76	98.43	134.93	60.77	62.52	102.13	112.19	100.58	89.90
1998Q1	94.69	99.00	138.30	95.11	96.70	127.85	72.19	64.24	98.63	119.31	104.06	93.41
1998Q2	96.13	101.09	145.37	95.51	98.43	134.01	64.25	67.04	105.17	117.90	110.57	90.47
1998Q3	89.65	97.00	142.37	90.80	94.20	129.60	61.86	65.16	97.70	112.30	104.60	74.41
1998Q4	96.96	97.08	147.57	97.97	94.37	135.26	57.20	61.00	101.17	118.20	112.42	79.21
1999Q1	104.26	105.17	147.53	104.23	103.23	136.25	68.21	70.64	105.13	120.45	114.48	87.35
1999Q2	102.18	106.84	149.07	102.10	104.75	136.82	71.40	73.01	108.27	121.46	117.19	89.12
1999Q3	100.43	103.49	152.53	100.74	101.94	138.55	69.92	71.15	106.03	135.62	122.27	87.12
1999Q4	109.53	111.51	161.27	110.63	109.94	147.41	68.95	70.36	111.40	145.61	132.75	93.20
2000Q1	110.19	116.80	157.13	110.22	115.40	145.12	72.76	73.02	114.57	154.57	133.31	106.68
2000Q2	112.20	123.25	163.87	111.93	120.08	150.69	78.73	79.41	122.23	159.18	139.07	101.90
2000Q3	106.03	116.50	153.80	103.34	115.13	140.38	77.97	79.89	110.00	171.84	141.47	101.80
2000Q4	116.31	116.83	173.07	117.87	116.32	158.97	75.76	75.50	123.83	167.22	138.98	97.96
2001Q1	129.71	131.32	187.40	129.74	130.48	173.04	80.10	82.69	140.87	169.23	137.62	107.76
2001Q2	123.01	136.09	181.03	123.55	133.74	166.74	86.54	91.44	137.57	167.15	144.67	107.21
2001Q3	112.50	124.61	170.23	113.26	122.83	155.36	81.33	85.27	122.00	176.25	144.26	102.99
2001Q4	110.63	113.21	161.53	111.26	111.99	148.90	70.95	72.81	113.47	150.65	129.49	98.20
2002Q1	119.83	122.80	174.70	120.55	122.32	162.42	75.18	78.21	129.30	147.72	125.08	102.34
2002Q2	107.04	115.88	160.67	107.51	113.96	146.31	73.65	77.40	118.90	136.20	121.63	94.90
2002Q3	105.62	110.74	159.33	105.99	109.34	143.66	66.37	72.26	110.97	123.92	113.30	88.39
2002Q4	114.55	113.18	172.50	115.32	112.05	158.10	64.20	67.65	120.17	127.02	117.08	93.02
2003Q1	126.38	121.16	184.87	127.14	120.97	170.93	71.29	71.94	135.53	136.19	118.47	97.68
2003Q2	106.40	109.66	169.80	106.48	108.13	153.95	64.85	65.91	128.80	133.52	118.95	99.18

APPENDIX VIIIB CONT'D

2003Q3	62.60	64.52	176.80	64.63	63.50	159.50	31.30	30.80	126.97	107.46	95.55	104.33
2003Q4	93.51	92.41	199.97	94.84	90.96	182.33	32.20	25.60	144.77	119.20	104.54	111.23
2004Q1	95.67	91.86	166.60	96.81	90.44	153.56	39.03	31.20	129.37	89.80	80.19	111.50
2004Q2	91.37	91.99	184.37	92.05	88.54	169.09	39.22	36.91	144.00	98.09	88.54	122.45
2004Q3	85.52	86.34	172.03	85.56	82.16	156.72	35.04	36.32	128.33	86.77	73.38	129.12
2004Q4	93.67	86.87	164.30	94.06	84.48	151.47	33.70	31.27	122.10	102.20	88.05	125.13
2005Q1	98.65	100.55	169.97	98.67	98.40	157.66	38.54	37.50	133.13	115.12	103.62	129.75
2005Q2	93.11	99.14	170.63	93.25	95.37	155.99	36.93	41.38	133.73	106.90	101.49	136.05
2005Q3	98.08	104.36	154.60	97.88	100.88	140.99	46.73	51.85	116.50	126.04	111.70	130.00
2005Q4	104.60	108.16	168.77	104.82	105.52	154.11	45.99	41.19	126.83	134.63	116.01	126.00